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A Microstrip Antenna Model for Clinical Monitoring Applications

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***Abstract*— The use of microstrip antenna in microwave imaging for clinical assessment assistance has grown to a great extent. In this paper, an inset feed defected ground structure rectangular patch antenna with Rogers RT/duroid 5880 as the substrate material is designed in the frequency range of 4.80 GHz to 5.80 GHz for clinical diagnosis assistance. A four layered human head phantom model is used for evaluation in Ansys HFSS electromagnetic simulation. The suggested antenna is simulated over the head phantom model in three different positions i.e., over the head phantom model free of tumor, over the head phantom model with a superficial tumor region of 6mm radius and over the head phantom model with deep-seated tumor. The quantitative assessment of the proposed technique is conducted using different antenna parameters, such as: radiation efficiency, reflection factor, co-polarization, cross-polarization, surface current in comparison to the cutting-edge techniques. Graphical representation of the parameters is also presented in order to conclude the presence of tumor inside the brain.**

***Index Terms*— Microstrip patch antenna, Brain tumor MR imaging, RFID, Smart healthcare applications.**

I. Introduction

IN clinical practice, monitoring the cutaneous and sub-cutaneous tumorous regions using medical imaging is widely appreciated. The early detection of tumor may help in the treatment planning by reducing the casualty to an extent. However, a regular imaging using high radiation may worsen the condition of the patient by increasing the tumor cells. The monitoring of deep-seated tumor is still remaining a key challenge. Hence forth, we are motivated to design an antenna model, which can monitor the tumorous and healthy cells inside the brain without worsening the patient condition. In this paper, we modelled a defected ground rectangular microstrip antenna with inset feed technique for monitoring the clinical status of the tumor regions in the brain. In addition, it may also assist the physician for telemedicine and treatment planning.

In the literature, many imaging modalities are reported in solving the problem on hand. Microwave imaging (MWI) is a widely used clinical monitoring system for brain related diseases. The MWI system provides potential results in real time applications while less harmful due to low radiation. The medical microwave imaging system operates by utilizing the differences in permittivity and conductivity between healthy and tumorous cells within the brain [1]. The tumor cells are having higher dielectric constant than the healthy cells. It results in a significant variation in the back-scattered signals while observed using a miniature antenna. From the studies, it has been noted that alterations in the dielectric constant result in substantial modifications to the backscattered signals [2]. An elliptical patch antenna with an ultra-wideband range for observing the skin cancer is proposed in [3]. The antenna used polytetrafluorothylene as the substrate material. The antenna is experimented with three layered substrates i.e., indium tin oxide layer is sandwiched in between a Roggers5880 layer bellow and a polytetrafluorothylene layer on top. A three-layer phantom with layers of skin, muscle and bone is created and an antenna array is simulated over the phantom. In order to evaluate the performance of the array, the reflection coefficient is measured both in air and over the phantom.

A microstrip patch antenna with FR4 substrate and copper as the radiating element is presented [4]. The antenna is tested in the ISM (Industrial, Scientific and Medical) test band and a human head model is constructed consisting of six layers, including skin, cerebrospinal fluid (CSF), dura, skull, fat, and brain tissue region. The antenna's performance is simulated over the head model both with and without a tumor present in the brain tissue region. The reported results show the presence of tumorous decreases the return loss as well as decreases the efficiency. An ultra-wideband microstrip antenna is proposed using graphene-based conductor (GBC) for detecting the brain tumor [5]. The antenna design modelled by changing the ground plane. The return loss performance is increased with the use of partial ground plane. The antenna is experimented over a head model having the 20mm as the distance. The presence of the tumor inside the brain is examined by analysing the change in S11 values. The reflected power of the antenna is more while there is a tumor inside the head. A pentagon shaped coplanar waveguide feed (CWF) microstrip patch antenna is reported for brain disease diagnosis [6]. The antenna is developed using FR4 as the substrate material and copper is used as the radiating element. A 5mm tumor is placed inside a six-layer human head model. Different antenna parameters, such as return loss, VSWR and radiation pattern

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are reported for comparison of the designed antenna over the head models with and without tumor. It is observed that the antenna showed a frequency shift at resonant frequency when simulated over a healthy and tumor model.

A patch antenna with two different electro-magnetic band gap (EBG) is proposed [7]. The antennas are having a rectangular lattice slot and a squared lattice slot, both resulting a 19% and 27% increase in return loss, respectively. Further, the EBG results in a 2.9% shift in return loss in the resonant frequency when compared to a head model with and without defected cells. Directivity, S11, electric fields, magnetic fields and current density are used for performance comparison. These parameters are also computed with two and four antenna elements in order to provide better penetration through the human tissues. A CWF planar antenna is proposed to detect tumour inside human brain [8]. The model used a coplanar waveguide feed planar antenna having Rogers RT 6002 as the substrate. A human head model having skin, fat, bone, brain layers with unique electrical properties is designed. Different antenna parameters like E-field, S11, SAR, current density is evaluated for the comparison purpose. A rectangular patch antenna with FR4 substrate which works in ISM band is developed [9]. The antenna is developed with and without slots in its radiation patch. A six layered head model (skin, fat, skull, CSF, dura and brain) is used for examination purpose. A tumor is placed inside the brain in different positions. Different antenna parameters like E-field, H-field, S11, SAR are examined for each case.

A *T*-slotted single feed compact microstrip antenna is proposed that operates in the ISM test band [10]. The antenna is simulated using a six layered human head phantom free of tumor and with tumor. In order to justify the detection of the tumor, the antenna is tested with the head model by positioning the tumor at different location. The reported model shows that the reflection ratio of the designed antenna is reduced, and the resonance shifted by a major value. A six layered head phantom is simulated using a patch antenna with rectangular strip line and FR4 substrate [11]. The model is simulated on both the tumor free model and tumor affected model. Different antenna parameters like S11, surface current, radiation efficiency, and directivity are observed for both the cases. A CPW feed pentagon shape patch antenna with FR4 substrate to be operated in ISM test band is developed [12]. A six layered head model is used for testing the performance of the antenna. For validation purpose, the authors used parameters like return loss, VSWR, radiation pattern of the antenna over the head phantom model. A pentagon shaped patch antenna with FR4 substrate is reported for microwave imaging [13]. The antenna is tested over a wideband starting from 3.30 GHz to 12.60 GHz. The antenna model is simulated over a brain phantom model with three layers i.e., skin, skull and brain tissues. The reported results conclude that the antenna showed a high reflection in presence of the tumorous tissues.

From the above, it is comprehended that the challenges are still existing, such as: maximizing the parameters variation for with defected cell and without defected cell in the head model. With aid of this, it will be more convenient to discriminate when the variation is well visible and will not cause confusion. This will lead to a better and safe examination which is still lacking. In this paper, a rectangular inset feed microstrip patch antenna is modelled using Rogers RT/duroid 5880 as the substrate for addressing the discussed problems. To increase the antenna parameters, inset feed technique is considered with a rectangular defect in the ground. A four layered human head model is developed using HFSS software and a tumor of 6mm radius is placed at different location in the brain. The antenna is simulated keeping a distance of 10mm from the head phantom. The analysis is done for the head model considering the tumor inside and also for the model free of the tumor. Different parameters, such as: return loss, radiation efficiency, co-polarization & cross-polarization, surface current is examined in order to validate the performance of the proposed antenna. This work is also maximizing the parameter difference between observed values with and without tumor in the head. The antenna may also be used to determine the presence of superficial as well as deep-seated tumors. While the antenna model is applied over the head model free of tumor, having a superficial tumor and also with the same tumor placed deep inside the brain model, the S11 parameter decreases, and a significant difference is observed.

The paper is progressed in three sections, as follows: Section II is explaining the modelling of the proposed antenna and the head phantom model used in testing purpose. The findings are discussed in Section III. Finally, the conclusion of this work is stated in Section IV.

II. Methodology

In this segment, we elaborate the design of the proposed antenna and its working on a head model. A detailed idea of the proposed model is presented as a flowchart in Fig. 1.

A. The Antenna Model

The proposed antenna is modelled as a defected ground structured inset feed rectangular microstrip antenna using Rogers RT/duroid 5880 substrate. The standard antenna parameters, such as: patch width (W_p), patch length (L_p), normalised length extension (ΔL), effective length (L_{eff}), etc. are calculated using the following expressions:

$$W_p = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

$$L_p = L_{eff} - 2\Delta L \tag{2}$$

$$\Delta L = 0.412h \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W_p}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W_p}{h} + 0.8\right)} \tag{3}$$

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \tag{4}$$

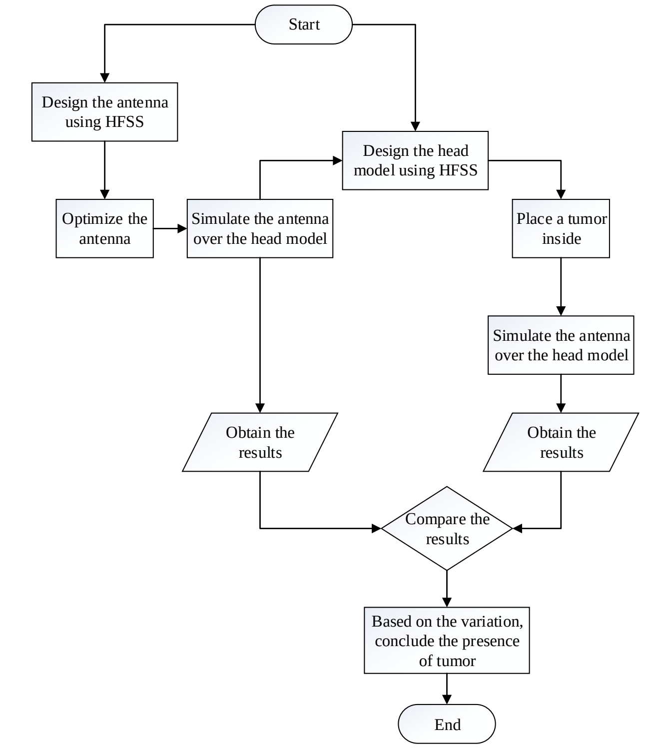


Fig. 1. Workflow diagram of the proposed wearable microstrip patch antenna for brain tumor monitoring.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W_p}\right]^{-1/2} \quad (5)$$

where, ε_r is the dielectric constant, c is the velocity of light, f is the resonant frequency, ε_{reff} is the effective dielectric constant, h is the thickness of the substrate material.

The dimension of the patch and feedline, such as: substrate length (L_s), width of the substrate (W_s), feedline length (L_f), are calculated using the following expressions:

$$L_s = L_p + 6h \quad (6)$$

$$W_s = W_p + 6h \quad (7)$$

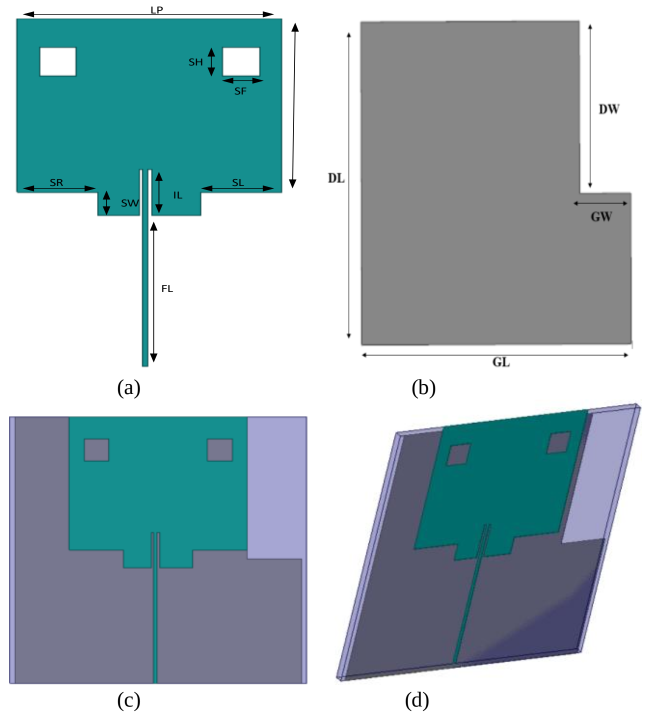
$$h = \frac{0.0606\lambda}{\sqrt{\varepsilon_r}} \quad (8)$$

$$L_f = \frac{\lambda_g}{4} \quad (9)$$

$$\lambda_g = \frac{\lambda}{\sqrt{\varepsilon_{reff}}} \quad (10)$$

where, L_p, h, W_p carries the same meaning as used in antenna patch and λ_g is the guided wavelength.

The substrate material is preferred to be Rogers RT/duroid 5880 because of its lower dielectric loss, better performance at high frequencies, light weight, lower moisture captivation. To improve the impedance matching, inset feed technique is preferred in the antenna design. Fig. 2 shows (a) the ground plane, (b) the patch of the antenna structure, (c) the top-view



(a) (b) (c) (d)

Fig. 2. The proposed antenna design, (a) geometry of the patch, (b) geometry of the ground plane, (c) top view of the proposed antenna, (d) side view of the proposed antenna.

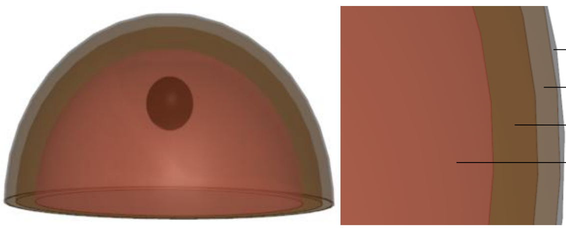
and (d) side-view of the antenna model, respectively. For easy visualization, green color is used for indicating the radiating material, grey color is used for substrate material and the ground plane is indicated with transparent violet color. Initially, the dimensions of the ground plane and substrate are kept as 60×60×1.6 mm^3. For improving the radiation characteristics of the designed antenna, the ground plane dimension is reduced to 58×60×0.1 mm^3 and a defected ground structure is introduced [14]-[21]. The radiating element is designed using a copper sheet of dimension 30×30×0.1 mm^3. To increase the return loss (S11) of the antenna model, a stair of 14×4 mm^2 is added to the patch, as shown in Fig. 2(a). Two slots of 5×5 mm^2 is realized in the radiating element to further increase the performance. The antenna is fed through a rectangular microstrip feedline of 26×0.7 mm^2. A detailed parameter values of the proposed antenna design is given in Table I.

TABLE I
ANTENNA DIMENSION AND MEASUREMENTS IN THE PROPOSED ANTENNA MODEL

Parameter	Measurement (mm)	Parameter	Measurement (mm)
LP	36	SH	5
WP	30	SF	5
SR	11	GW	60
SL	11	GL	58
SW	4	DW	32
IL	8	DL	11
FL	26	GW	60

B. The Head Model

To verify the antenna performance, a head phantom model is simulated using Ansys HFSS 15.0 software in electromagnetic simulation environment. The model is a replication of the human brain, therefore actual size will be larger. The phantom is modelled with four layers, such as skin, fat, bone and brain region. The layers are discriminated from each other by unique thickness and dielectric properties, such as permittivity and conductivity. Since each layer is modelled with unique specifications, it is obvious that each layer possesses unique characteristics. A tumor region of 6mm radius is included inside the brain layer of the phantom model. The detail of the head phantom model is given in Table II. Fig. 3 shows the simulated human head phantom model and the sequencing arrangement of the four different layers.



(a) (b)

Fig. 3. Human head phantom model, (a) head model with deep seated tumor, (b) four different layers in the head model.

C. Simulation of Antenna over the Head Model

Fig. 4 shows a model structure of the designed antenna for monitoring the brain tumor in smart health care applications. As of the illustration, the antenna radiates EM wave on the human head. The EM wave intercepts the human head and a portion of the radiated power gets reflected. The reflected power is having variations in its power due to the permittivity difference in the human brain. The presence of a tumor or the variation of its clinical status is monitored in the analyser. The analyser shows high return loss in absence of the tumor or the detected tumor with no change in clinical status. The decrease in return loss alerts the observer for medicine or treatment planning. The designed antenna is simulated with the head model free of tumor and having a tumor inside.

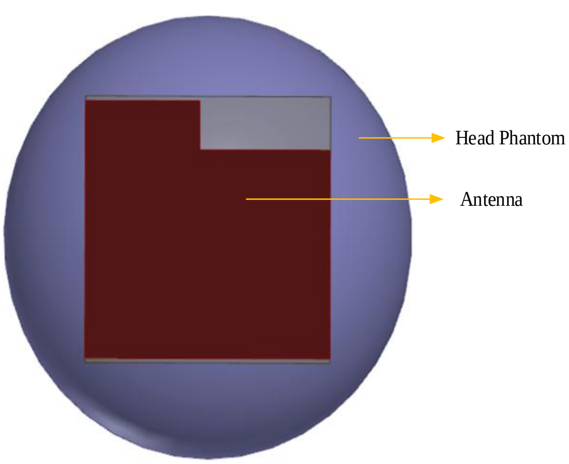


Fig. 4. The overview arrangement of the proposed technique.

In Table II, the electrical specification of the simulated head model with the details of different material properties, such as: conductivity, relative permittivity or dielectric constant and thickness, are given.

TABLE II
ELECTRICAL SPECIFICATION OF THE SIMULATED HEAD MODEL

Tissue	Conductivity (S/m)	Relative Permittivity	Thickness (mm)
Skin	0.73	45	0.5
Fat	0.04	5.54	2.5
Skull	0.03	5.6	5
Brain	43.22	1.29	68
Tumor	7	55	12

III. RESULTS AND DISCUSSION

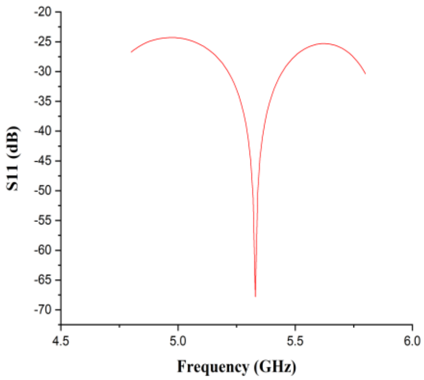
The proposed antenna and the head phantom models are simulated using Ansys HFSS 15.0 software in a standard workbench setup. The antenna parameters such as return loss, radiation efficiency [22], polarization [23] and surface currents [24] are taken for the comparison and validation purpose. In this section, the results of the proposed design are presented in the form of figures and tables with a comprehensive discussion.

A. Reflection Factor (S11)

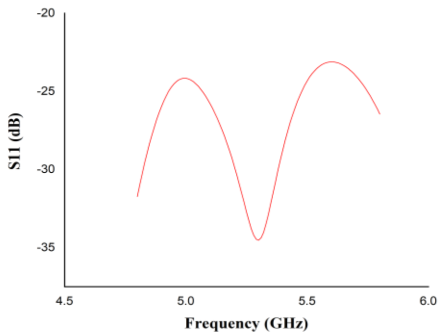
The reflection factor, also known as the return loss, is a measure of the electromagnetic energy that an antenna receives and is typically expressed in decibels (dB). A lower value of the return loss indicates that the antenna is receiving less energy, which can reduce its effectiveness. As the proposed antenna in this work is focused for applications over human body, keeping this as primary consideration a better i.e., high magnitude of reflection factor measurement is always desirable.

Fig. 5 shows the return loss plotting of the proposed design over the head model without tumor, with tumor at surface (superficial tumor) and with tumor deep inside (deep-seated tumor). From the figures, it is observed that, the return loss plot obtained using the head phantom model gives about -70dB loss, as in Fig. 5(a), whereas it shows about -35dB loss while a tumor region exists inside, as in Fig. 5(b), indicating the presence of tumor mass inside the head region.

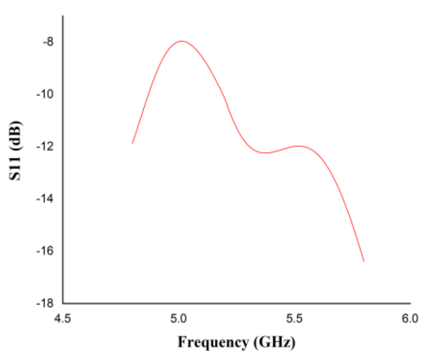
Return loss is measured for three different cases i.e., for the tumor-less head phantom, head-phantom with a tumor of 6mm radius placed not much deep inside the head and the same tumor placed deep inside the head. A return loss with higher magnitude is obtained with a starting frequency from 4.8 GHz to 5.8 GHz as in Fig. 5(a). A sharp edge resonance peak of -67.8 dB is observed at 5.33 GHz for the case without a tumor in the head. For the case of the head model with a tumor inside the head, the observed return loss decreased to -33.51 dB at 5.33 GHz as in Fig. 5(b). When the tumor is moved away from the outer layer of the brain, it is observed that the return loss is decreasing further i.e., -12.17 dB at 5.33 GHz as in Fig. 5(c).



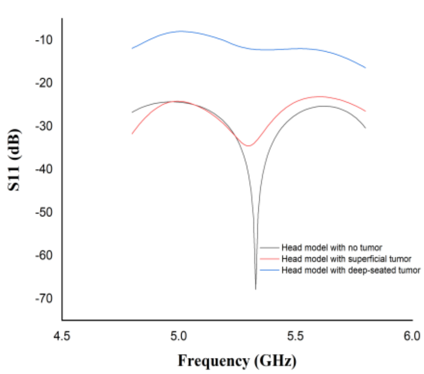
(a)



(b)



(c)



(d)

Fig. 5. Tabulation of the S11 parameter of the antenna with tumor placed at different position in the head model (a) without tumor, (b) not much deep, (c) tumor placed deep inside, (d) comparison of (a), (b), & (c).

Fig. 5(d) shows a cumulative comparison of the return loss parameters observed in all three cases. The variation in the electrical properties of different layers of human body provides significant changes to the back scattered signals. From Fig. 5, it is observed that the return losses are different when there is no tumor and there is tumor present in the head phantom model. As the dielectric properties of the tumor region is much higher than that of other head layers as in Table II. In presence of tumor, return loss value is decreasing than that of the observation recorded without the tumor. It is also observed that when the tumor is shifted down inside the head, the return loss is further decreasing. From this study, it is concluded that the presence of tumor inside the head phantom model can be monitored, detected and analyzed independent of the position of the tumor.

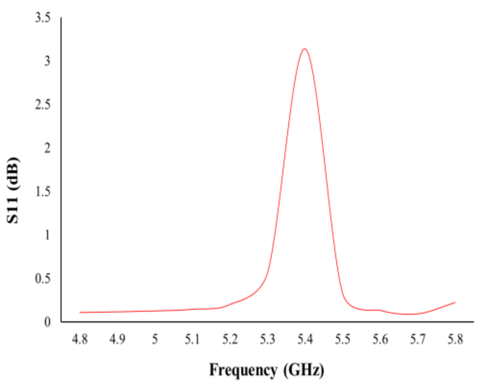
Table III presents a quantitative assessment of the proposed antenna with the state-of-the-art designs using S11 parameter. The best-in-class values in the table are indicated using bold faces. The non-availability of the data is indicated by a '-' symbol. The values in the table depicts the superior directivity performance of the proposed antenna model over the compared models.

TABLE III
COMPARISON OF THE PROPOSED MODEL WITH THE STATE-OF-THE-ART MODELS USING S11 PARAMETER.

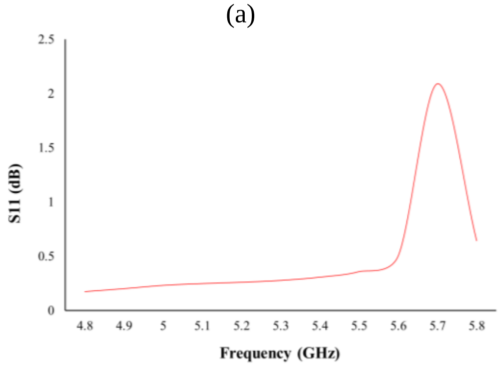
Methods	S11 without tumor (A)	S11 with tumor in surface (B) (in dB)	Difference (A-B)	S11 with tumor in deep (C) (in dB)	Difference (A-C)
Proposed	**-67.8**	**-33.51**	**-34.29**	**-12.17**	**-55.63**
Sinha et al. [4]	-22.299	-22.308	0.0087	-22.310	0.010063
Chowdhury et al. [6]	-30.994	-31.42	0.426	-	-
Elkorany et al. [7]	-11.17	-9.06	-2.11	-	-
Singh et al. [8]	-17.6	-18.19	0.59	-	-
Al-Nahiun et al. [11]	-30.87	-30.76	-0.11	-	-

B. *Radiation Efficiency (η)*

Radiation efficiency (RE) refers to the ability of an antenna to convert electrical power into electromagnetic radiation. It is a measure of the portion of the total input power that is converted into useful radiation, expressed as a percentage. The radiation efficiency (η) or RE of the proposed antenna is evaluated for three different cases i.e., for the tumor-less head phantom, head-phantom with a tumor of 6mm radius placed just below the surface of the head and moving further inside the head. The results are shown below, in Fig. 6. From Fig. 6(a), it is clearly observed that when the proposed antenna model is applied over a tumor less head model, the antenna is yielding a better radiation efficiency at 5.2 GHz to 5.4 GHz with a sharp resonance peak of 3.137732dB at 5.4 GHz. While the tumor is present inside the head, it is observed that the values are decreasing up to 2.088366 dB at about 5.6 GHz to 5.8 GHz with a resonant frequency observed at about 5.7 GHz, as in Fig. 6(b). While, a tumor is placed deep-seated in the head model, it is observed that the radiation efficiency further decreases in a significant value, showing two resonance peaks of 0.455488 dB and 0.584344 dB at 5.2 GHz and 5.5 GHz, respectively, as shown in Fig. 6(c). From the observation of the radiation efficiency observations, we conclude that the radiation efficiency decreases with the presence of tumor at superficial and further decreases with deep-seated tumor.



(a)



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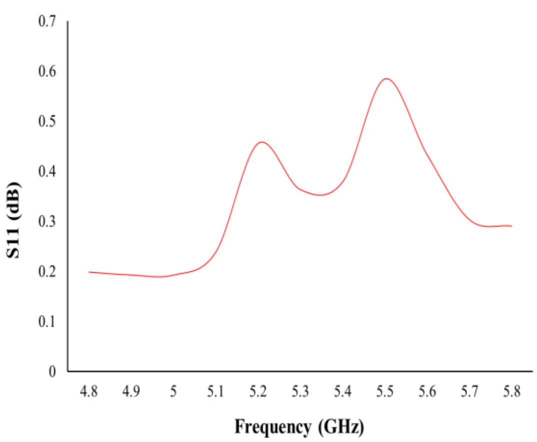
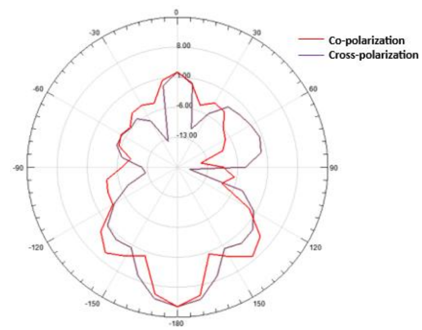


(c)

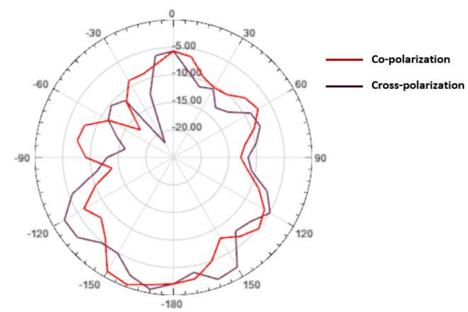
Fig. 6. Radiation efficiency of the antenna model, (a) without tumor, (b) with tumor placed not so deep inside, (c) with tumor placed deep inside.

C. Polarization and Surface Current

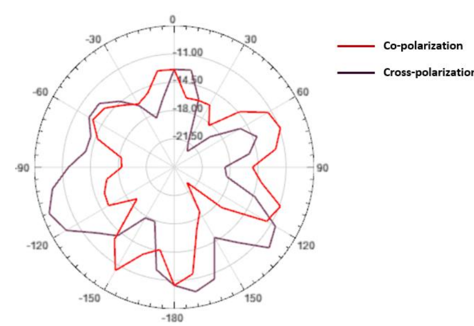
Co-polarization and cross-polarization are terms used to describe the orientation of the electric field (E-field) and magnetic field (H-field) components of electromagnetic waves radiated by an antenna. Fig. 7 shows the radiation pattern plot of the antenna model. In Fig. 7(a), the current distribution of the radiation patterns of the proposed antenna with head phantom model without tumor region is showing a value up to 12.00 dB. Whereas polarization distribution of the radiation pattern in the form of co-polarization and cross-polarization are up to maximum of 0dB in Fig. 7(b). From Fig. 7(c), it is observed that the radiation pattern plot of the antenna shows more reduced power, i.e., about -10dB.



(a)



(b)



(c)

Fig. 7. Polarization plot of the proposed antenna on the head model, (a) without tumor region, (b) with the tumor placed on surface, (c) tumor placed deep inside.

Analysis of the above figures reveals that when the antenna is utilized over a head phantom model with a defected cell inside, the cross-polarization curve coincides with the co-polarization curve, thus indicating the presence of a tumor in the head.

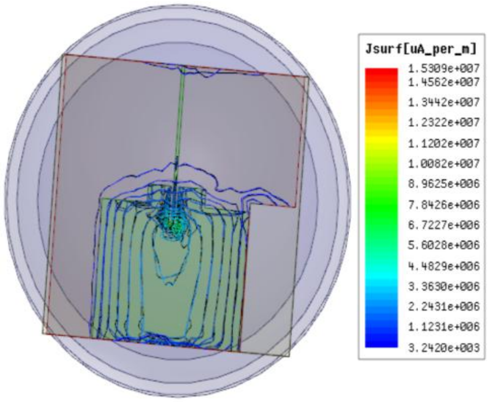


Fig. 8. Surface current of the head phantom with tumor.

The applied EM field causes a real time electric current induction, referred to as surface current, mainly in metallic and dielectric antennas. Fig. 8 shows the surface current plot of the proposed model after simulating the proposed antenna over the four-layered head phantom model having a tumor inside.

IV. Conclusion

In this paper, a defected ground structured inset feed rectangular microstrip antenna with Rogers RT/duroid 5880 substrate is suggested for brain tumor monitoring and analysis. From the result analysis, it is observed that when there is a tumor in the head, the antenna parameters return loss and radiation efficiency are decreasing than that of the values calculated in absence of the tumor. It is also observed that these values are further decreasing when there is a deep-seated tumor present in the head phantom model in comparison to calculated values in presence of a superficial tumor. It may be due to the modified ground structure and the inset feed of the proposed antenna model. When the tumor is absent from the head model, the antenna demonstrates a significant difference in the measured return loss values. The comparison of the proposed model in comparison to the cutting-edge approaches gives the efficacy of the suggested model. This work can be further carry forwarded to making the antenna conformal. Further, the antenna can be fabricated and tested with real time clinical environment.

References

[1] M. Rokunuzzaman, M. Samsuzzaman, and M.T. Islam, "Unidirectional wideband 3-D antenna for human head-imaging application," *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 169-172, May 2016.

[2] M. Lazebnik, D. Popovic, L. McCartney, C.B. Watkins, M.J. Lindstrom, J. Harter, S. Sewall, T. Ogilvie, A. Magliocco, T.M. Breslin, and W. Temple, "A large-scale study of the ultrawideband microwave dielectric properties of normal, benign and malignant breast tissues obtained from cancer surgeries," *Physics in Medicine & Biology*, vol. 52, no. 20, p. 6093.

[3] S. Alani, Z. Zahriladha, and A. Ahmad, "Miniaturized UWB elliptical patch antenna for skin cancer diagnosis imaging," *International Journal of Electrical & Computer Engineering*, vol.10, no. 2, pp. 1422-1429, Apr. 2020.

[4] S. Sinha, T.S. Niloy, R.R. Hasan, M.A. Rahman, and S.A. Rahman, "A wearable microstrip patch antenna for detecting brain tumor," *in Proceedins of International Conference on Computation, Automation and Knowledge Management* (ICCAKM), pp. 85-89, Jan. 2020.

[5] M.A. Aziz, M.M. Rana, M.A. Islam, and R. Inum, "Effective modeling of GBC based ultra-wideband patch antenna for brain tumor detection," *in Proceedings of International Conference on Computer, Communication, Chemical, Material and Electronic Engineering* (IC4ME2), pp. 1-4, Feb. 2018.

[6] T. Chowdhury, R. Farhin, R.R. Hassan, M.S. Bhuiyan, and R. Raihan, "Design of a patch antenna operating at ISM band for brain tumor detection," *in Proceedings of International Conference on Advances in Electrical Engineering* (ICAEE), pp. 94-98, Sep. 2017.

[7] A.S. Elkorany, R.M. Helmy, A.A. Saleeb, and N.F. Areed, "Microstrip patch antenna linear arrays for brain tumor detection," *in Proceedings of International Conference on Computer Engineering and Systems* (ICCES), pp. 425-431, Dec. 2019.

[8] T. Singh, S. Singh, M. Singh, and R. Kaur, "Design of patch antenna to detect brain tumor," *in Proceedings of International Conference on Issues and Challenges in Intelligent Computing Techniques* (ICICT), vol. 1, pp. 1-6, Sep. 2019.

[9] M. Dishali, K. Jeba, K. Madhan, and N. Mustafa SM, "Design of microstrip patch antenna for brain cancer detection," *ICTACT Journal on Microelectronics*, vol. 5, no. 1, pp. 731-737, Apr. 2019.

[10] M. S. Nesar, N. Chakma, M. A. Muktadir, and A. Biswas, "Design of a miniaturized slotted T-shaped microstrip patch antenna to detect and localize brain tumor," *in Proceedings of International Conference on Innovations in Science, Engineering and Technology* (ICISET), pp. 157-162, Oct. 2018.

[11] S. A. Al-Nahiun, F. Mahbub, R. Islam, S. B. Akash, R. R. Hasan and M. A. Rahman, "Performance analysis of microstrip patch antenna for the diagnosis of brain cancer & tumor using the fifth-generation frequency band," *in Proceedings of International Conference on IOT, Electronics and Mechatronics.* (IEMTRONICS), pp. 1-6, Apr. 2021.

[12] R. Raihan, M.S. Bhuiyan, R.R. Hasan, T. Chowdhury, and R. A. Farhin, "Wearable microstrip patch antenna for detecting brain cancer," *in Proceedings of International Conference on Signal and Image Processing* (ICSIP), pp. 432-436, Aug. 2017.

[13] S. Rosaline, K. Kannan, R. Krishnan, S. Vanaja, and J. J. Sheela, "Detection of Tumor in Nervous tissue Using Radar Based Design," *in Proceedings of International Conference on Computer Communication and Informatics* (ICCCI), pp. 1-6, Jan. 2021.

[14] D. Guha, S. Biswas, and C. Kumar, "Printed antenna designs using defected ground structures: a review of fundamentals and state-of-the-art developments," *in Proceedings of Forum for electromagnetic research methods and application technologies* (FERMAT), vol. 2, pp- 1-13, May. 2014.

[15] J. M. Sh-Ali, "Performance of Defected Ground Structure for Rectangular Microstrip Patch Antenna," M.S. thesis, Dept. Elect. Eng., Universiti Tun Hussein Onn Malaysia, Johor, Malaysia, 2021.

[16] J. S. Lim, H. S. Kim, J. S. Park, D. Ahn, and S. Nam, "A power amplifier with efficiency improved using defected ground structure," *IEEE Microwave and Wireless Components Letters*, vol. 11, no. 4, pp. 170-172, Apr. 2001.

[17] C. Vandana, K. Maninder, K.V.P. Singh, and K.J. Sumit, "Design and optimization of microstrip patch antenna with defected ground structure and circular slot on the patch," *International Journal of Research in Engineering and Technology*, vol. 07, no. 02, pp. 460-468, 2013.

[18] H. Takhedmit, B. Merabet, L. Cirio, B. Allard, F. Costa, C. Vollaire, and O. Picon, "A 2.45-GHz low cost and efficient rectenna" *in Proceedings. of European Conference on Antennas and Propagation*, pp. 1-5, Apr. 2010.

[19] Q. Zhou, G. Fu, and C. Sun, "High-gain low-profile circularly polarized patch antenna for universal RFID reader application," *Journal of Electromagnetic Waves and Applications*, vol. 36, no. 2, pp. 285-306, Jan. 2022.

[20] J. L. Jiménez-Martín, A. Parra-Cerrada, R. Fernández-Recio, D. Segovia-Vargas, L. García, and V. González-Posadas, "Dual band and dual polarization short-circuited ring patch antenna," *Journal of Electromagnetic Waves and Applications*, vol. 30, no. 9, pp. 1198-1206, Jun. 2016.

[21] S. Tripathy, P. K. Mishro, B. P. Mishra, and V. Mukherjee, "A Defected Ground Structure Microstrip Antenna for Smart Healthcare Applications," *in Proceedings of International Conference on Paradigms of Communication, Computing and Data Sciences*, pp. 179-190, 2022.

[22] G. Vetharatnam, B. K. Chung, and H.T. Chuah, "Design of a microstrip patch antenna array for airborne SAR applications," *Journal of Electromagnetic Waves and Applications*, vol. 19, no. 12, pp. 1687-1701. 2005.
[23] J. S. Kang, J. H Kim, N. W. Kang, and D. C. Kim, "Antenna measurement using S-parameters," *in Proceedings of Conference on Precision Electromagnetic Measurements*, pp. 658-659, 2012.
[24] A. M. Alzahed, S. M. Mikki, Y.M. Antar, M. Clenet, and S. Jovic, "Characterization of a rectangular patch antenna using ACGFSEM approach," *in Proceedings of Conference on Antenna Measurements & Applications* (CAMA), pp. 1-3, Oct. 2016.

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