

Design and Analysis of Effective Vivaldi Antennas for Brain Tumor Detections: Ku Frequency Band

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Abstract—Our goal is to design different Vivaldi antennas with simple, small, and low cost. They can be used in Ku frequency band, which can be used for brain tumor detection in the presence of abnormal tissues or tumor. The whole work is divided by two parts, antenna design part and brain tumor detection part. The antenna is being designed to work properly across the given Ku frequency 13.5 GHz to 14.71GHz. For tumor detection, a multilayer brain model (skin, fat, bone and white matter) is designed using the CST microwave studio. Basically, the antenna is placed between the skull and white matter of brain model to radiate into brain tissues. We analyzed the return loss and 3dB point to ensure the presence of brain tumor. The measured specific absorption rate shows that it is within the patient safety range.

Index Terms—Antenna, biomedical application, and cancer detection.

I. INTRODUCTION

Brain cancer is the most common type of cancer and considered as major health problem [1], [2]. It occurs when abnormal cells within the brain. In this regard, the biomedical engineering holds a prominent place as a mean of improving medical diagnosis and treatment [3]. Brain tumor detection is a biomedical approach. In the ultra wideband (UWB) imaging system, a narrow pulse is being transmitted from a single applicator belongs to the annular array and then scattered with the different layer of the phantom [4], [5]. The scattered signal of different layer of brain tissue is collected by one or array of antennas surrounding in brain. The signal processing algorithm can then be used to investigate the existence of any cancerous tissues [6], [7]. There are many approaches based on the microwave image for cancer detection [8], [9], [4].

The vivaldi antenna claims extra attention to be used in the microwave brain imaging system as it acquires some unique characteristics [5], [10]. Now question arise which type of unique characteristics? The answer is that it can operate very high range of frequency (here we use Ku band in 12-18 GHz) which is a basic need for detection process, low cross polarization, and low cost [9]. As it is used for detection process so single Vivaldi antenna is not suitable in this respect [4]. Because single antenna can not capture the

maximum portion of brain like array antenna. Beside single antenna gain, directivity, return loss, voltage standing wave ratio (VSWR) are reasonable compared with existing method [11]. To get an optimized result, it will require to increase the number of Vivaldi antenna elements [12]. If the number of array is greater, then it is not only increasing the maintenance complexity but also cost [13]. Thus, the existing works are not sufficient to represent optimize result. Therefore, the goal is to optimize such an antenna array of Vivaldi to detect the tumor of brain which can perform better than the existence work.

The main contributions of this article are as follows:

- Design and analysis the Vivaldi antenna which can operate in Ku frequency band and apply for brain tumor detection.
- The performance of the designed antennas are verified in terms of radiation patterns, return losses, and voltage standing wave ratio (VSWR). It is observed that the return loss, VSWR, and half power bandwidth have increased when tumor is present in the brain model. When the tumor is absent, their results are better than the present of tumor.

II. BRAIN TUMOR DETECTION PROCESS

A brain tumor diagnosis can sound like a life-threatening situation [14], [15]. Although the symptoms of most brain tumors are the same, not all tumors are malignant. Fig. 1 shows an image of brain tumor. For tumor detection designed, antenna should be tuned to operating frequency and impedance. Scattered signal from the human body depends on electrical properties of the tissue like dielectric constant, and conductivity. These properties are different for normal tissue and tumor affected tissue. So, we have to measure the dielectric constant and conductivity of the skin [16]. Then we have to adjust or select the designed antenna for measured skin parameters. After that the antenna has to be positioned with direct contact of the skin or minimum distance from the skin. Finally, the antenna has to be operated at desired tuned frequency and impedance. Antenna characteristics with brain tissues and with tumor will be different. The difference will be



Fig. 1: Image of brain tumor.

caused due to high dielectric difference between brain tissue and tumor tissue. Fig 2 shows the working procedure of the tumor detection.

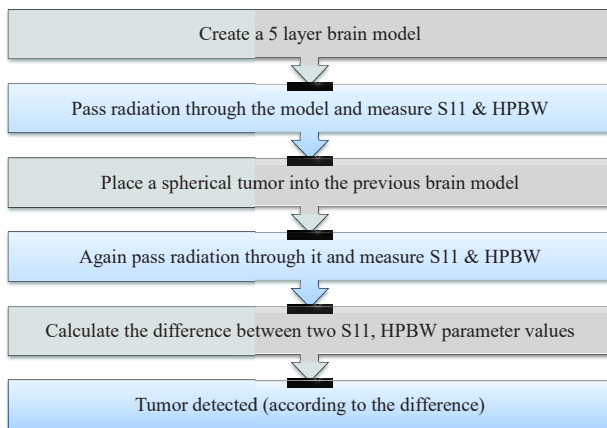


Fig. 2: Flow chart of the tumor detection process.

The CST 2016 microwave studio has different head related materials such as bone, fat, and skin as shown in Fig. 3. In this paper, Fig. 4 is used as a human brain model [17]. In this figure, the last layer teflon is used for isolation between the antenna ground plane and skin of human brain model [18]. The detail specifications of the brain model is shown in Table I.

TABLE I: Specifications of the brain model.

Description	Values (mm)	Description	Values (mm)
White matter (radius)	7	Bone (radius)	7.5
L_1	50 pH	R_2	0.04 Ω
Fat (radius)	8	Skin(radius)	8.5
Teflon (radius)	8.75		

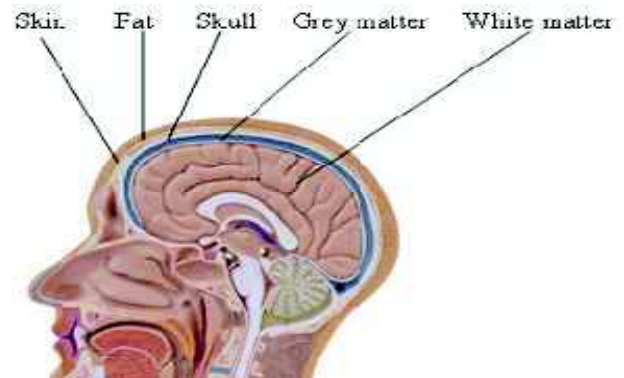


Fig. 3: Anatomical slices of the considered human head.

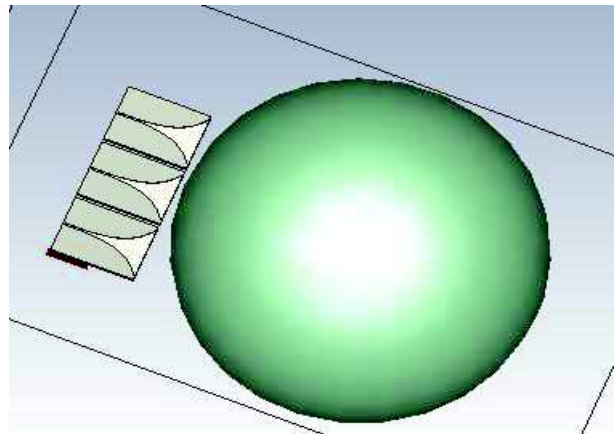


Fig. 4: Considered brain phantom for designing vivaldi antenna.

The tumor is represented as a 1 mm diameter sphere with dielectric permittivity 55 and conductivity 7 S/m [3]. The specifications of the tumor is given in Table II.

TABLE II: Specifications of tumor model.

Parameters	Values	Description	Values
Radius of the tumor model	1 mm	Dielectric constant	55
Conductivity	7 S/m		

III. SIMULATION RESULTS AND DISCUSSIONS

The general structure of the vivaldi antenna with feed line is shown in Fig. 6 [19], [20]. The radiation patterns with and without tumor are shown in Figs. 8-11.

It is intuitively observed that the return loss, VSWR, and HPBW have increased when tumor is present in the brain model. But when the tumor is absent, their results are better than the present of tumor. It occurs because of back scattered

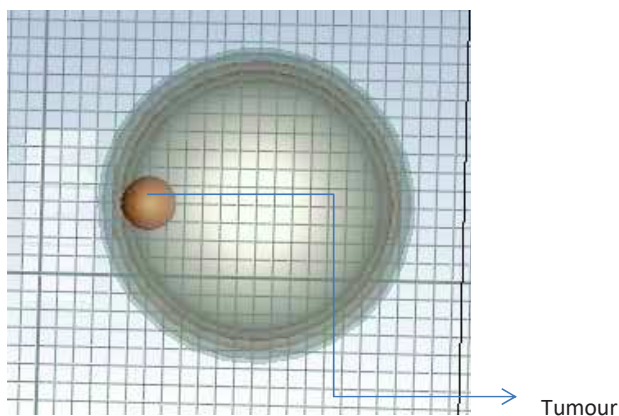


Fig. 5: Tumor model.

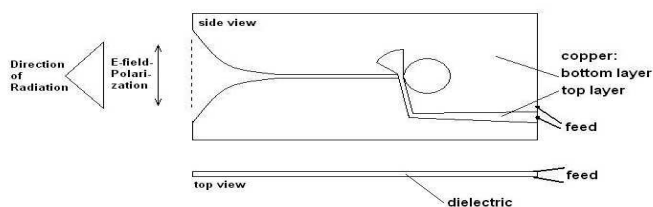


Fig. 6: General structure of vivaldi antenna with feed line.

of abnormal tissue (tumor). So, it is very easy to identify the presence of tumor by comparing the results of normal brain and tumor affected brain.

IV. CONCLUSION

We have designed Vivaldi antenna model to simulate for a brain cancer detection using the microwave imaging method. During this selection process, a lot of antennas array are being designed and verified to prefer the most suitable one. The detection results are presented here for the antenna which is very feasible. The operating frequency has set to an optimum value which causes less heating in human body. The SAR distribution through the brain model is much less than limiting value. Consequently, the designed antenna provides patient safety, less hazardous, low health risk, properly detect brain cancer at a curable stage, sensitive to tumors, involves minimal discomfort, provides easy to interpret, and consistent results. The detection method presented here can be used as early stage of tumor detection.

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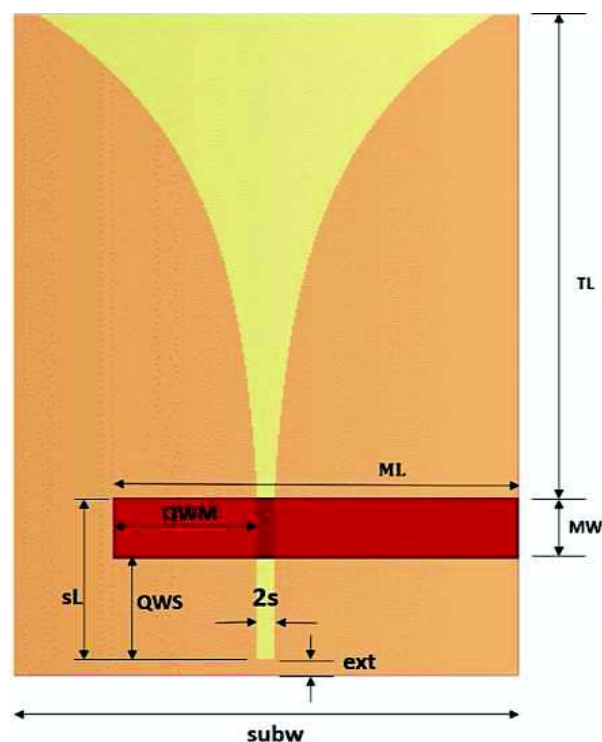


Fig. 7: Layout of designed Vivaldi antenna.

TABLE III: Specifications of proposed antenna [2].

Parameter	Dimension (mm)	Parameter	Dimension (mm)
S	0.05	SL	1
TL	3	Subw	3
Ext	0.1	H	0.2
QWM	0.9	MW	0.25
QWS	0.75	ML=	QWM+s+subw/2

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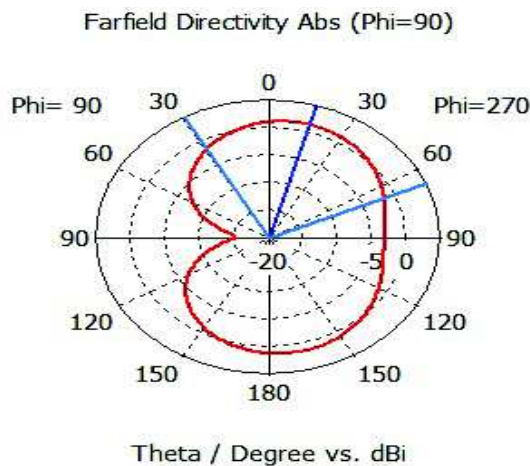


Fig. 8: Radiation pattern for 3-array Vivaldi brain model (without tumor) considering Frequency=10 GHZ, Main lobe magnitude= 1.97 dB, Main lobe direction=179 Deg, Angular width=99.5 Deg, and Side lobe level=-0.6 dB.

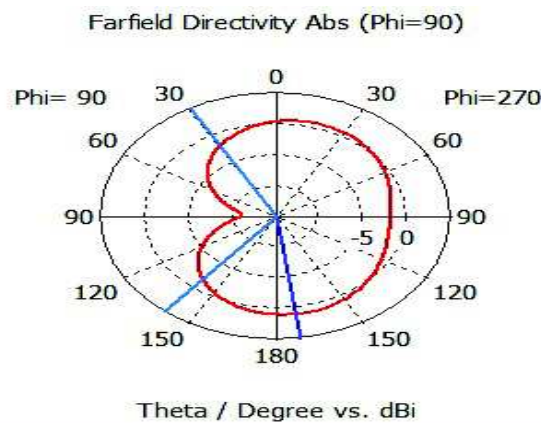


Fig. 9: Radiation pattern for 3-array Vivaldi brain model (without tumor) considering Frequency=10 GHZ, Main lobe magnitude= 1.97 dB, Main lobe direction=179 Deg, Angular width=99.5 Deg, and Side lobe level=-0.6 dB.

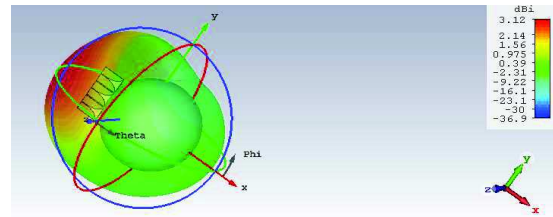


Fig. 10: 3D radiation pattern for 3-array Vivaldi antenna with brain model (without tumor).

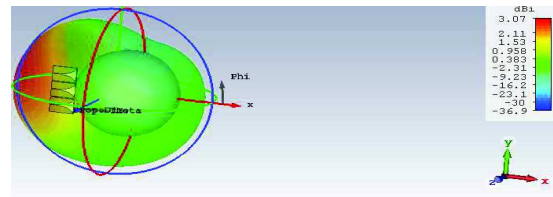


Fig. 11: 3D radiation pattern for 3-array Vivaldi antenna with brain model (with tumor).

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