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Design Of Uwb Vivaldi Antenna For Stroke Detection And Monitoring Based On Qualitative Microwave Imaging Technique

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Abstract- Microwave imaging is one of the emerging noninvasive portable imaging techniques which use non ionized radiations to take the detailed view of biological tissues in the microwave frequency range. In this paper Ultra wideband Vivaldi antenna is designed as a radar technology to view the properties of head tissue at a resonance frequency of 2.2GHz and 3.5 GHz. The proposed Vivaldi structure is simulated with FR-4 substrate (dielectric constant of 4.3, thickness of h=1.6 mm) using CST microwave simulation software (2020 version). This near field imaging arrangement is proposed for identification of blood clot/stroke at an early stage as well as for continuous monitoring.

Keywords: Near field imaging, stroke diagnostics, microwave tomography, S-parameter curve of the designed antenna, Antenna system

I. INTRODUCTION

Stroke is one of the major problems arising among elders. Brain injury often leads to death. Head imaging is necessary for the detection and identification of blood clot in the brain. Cerebrovascular accidents are the leading cause of death and disability among elders around the world. Generally, two types of stroke occur which are named as ischemic and hemorrhagic. Ischemic stroke occurs due to blockage of blood supply to the part of the brain. Hemorrhagic stroke occurs when the blood vessel bursts. Early action can minimize brain damage and potential complications. Present imaging systems used for detection of brain stroke is mainly computerized tomography (CT) and/or magnetic resonance imaging (MRI) [1]. CT uses ionized radiations and is focused on patients to generate cross sectional images. These cross-sectional images are called tomographic images and give more information about biological tissues compared to conventional X-Rays. But CT scan fails at the imaging of soft tissues. MRI does not use ionized radiations, but it is highly expensive and not suitable for pregnant women. Moreover, both techniques are time consuming and cannot be used for continuous monitoring [2]. The implementation of proposed system involves developing a portable device used in the ambulance set up for early recovery and timely care to the patients.

Microwave imaging is an important imaging modality during past few decades. There are two types of microwave imaging (Active and Passive microwave imaging). In Active type, object to be detected is illuminated by several transmitting antennas. The scattered field is measured by various receiving antennas. The reflections are collected and analyzed to detect the target area. This can be used for analyzing the dielectric parameters of human tissue. Generally, the permittivity of healthy tissues differs from tumor affected tissues. There is another type of microwave imaging called passive microwave imaging (Thermography) in which short pulses causes the cells temperature inside tissue to rise and radiometer is used for measurement of temperature. The resultant image obtained by this technique shows measured temperature variation of normal and malignant tissues. Any microwave imaging set up contains two parts: The first part involves calculation of distribution of electromagnetic field (scattering process) of a human head model. This is called forward problem. The second part is the inverse problem in which an image is reconstructed based on the scattering properties of tissue. A microwave helmet is designed with triangular micro strip patch antennas to distinguish between the ischemic and hemorrhagic stroke [3]. The first prototype" Stroke finder", developed at Chalmers University for the frequency range 0.8-1. 5GHz.Thisprototype contains 12 triangular patch antennas on a plastic helmet [4]. R. Scapaticci et al. in 2018 designed stroke detection system in which wide band monopole antennas with head mimicking phantom are used [5]. But it cannot be used to specify location and size of the blood clot/tumor. M. Salucci et al. designed an approach to classify the type of stroke from real time scattering data [6].

The human head is a no homogeneous tissue having different values permittivity. The difference between the normal and unhealthy tissue would be low for some tissues like head.

II. MICROWAVE IMAGING SYSTEM DESCRIPTION

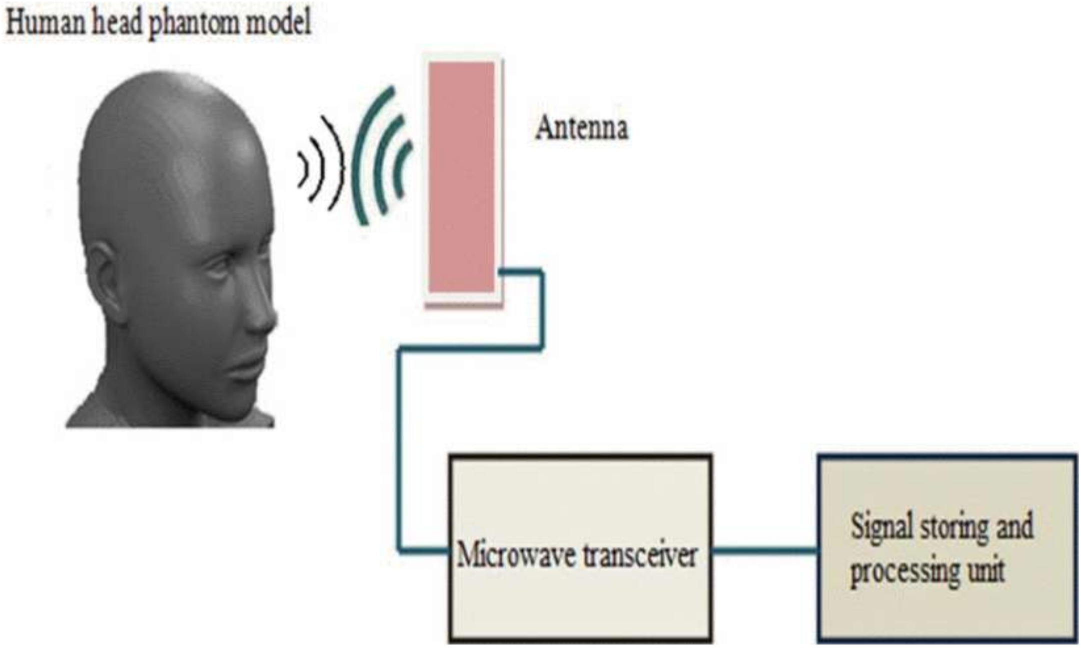

Figure 1. Microwave imaging system for human head [7]

The Figure 1 in the microwave sensing and imaging consist of two parts (hardware and software). The hardware includes transmitting and receiving antennas and Vector network analyzer for the measurement of dielectric profile of biological tissue. The software part is actually a reconstruction algorithm for creating detailed view of biological tissues. Radar based microwave imaging works based on the tissue characterization by different permittivity values. The discontinuities in tissue produces reflected electromagnetic waves from incident RF energy.

A. Human Head Phantom

Phantom is like an object which emulates the electrical properties of living tissue. The optimum frequency for the detection is 1-4GHz because it provides good penetration depth. A numerical head phantom for emulating human head is constructed. The brain size is designed based on the Zubal head phantom along with tumor size of 32 mm x 40 mm is studied [8].

B. Vector Network Analyzer

A vector network analyzer is a RF instrument used to measure both amplitude and phase of either transmitted or reflected waves. It is an instrument that measures the scattering parameters of an antenna system at high frequencies. Network analyzers used on networks with an arbitrary number of ports. The size of VNA can be further reduced by replacing it with software defines radio. SDR technology with LABVIEW software designed to produce better imaging data [9]. Kang-Chum et al. proposed a compact X Band Vector network Analyzer for low cost microwave imaging. But it fails to provide good resolution and the frequency range is not suitable for human head [10].

C. Antenna system

Antenna is an important part of microwave imaging system. Micro strip antenna, Dipole, Monopole and Vivaldi antenna types are preferred for Head imaging based on frequency of operation. Abdulrahman S. M et al proposed wearable antennas for head imaging based on polymer technology [11].

D. Image Reconstruction

Image reconstructions are of two categories namely Quantative or Iterative and Qualitative or Analytical methods. Quantative method reconstruction includes Newton type iterative Scheme, Born iterative method and Gauss Newton inversion. This approach is based on solving ill-posed inverse scattering problems based on minimization algorithm. Analytical approach uses strong scattered signal detection using radar technique such as co focal imaging and Space time beam forming. It is possible to use machine learning approach for detection and continuous monitoring of stroke patients. MATLAB contains a classification tool box for detecting and identifying the type of stroke using anyone of the supervised machine learning approach such as Support vector machine algorithm.

III. MICROWAVE IMAGING METHODS

Based on the reconstruction of images, microwave imaging is classified into two types (i) Quantative imaging (ii) Qualitative microwave imaging

A. Quantitative Imaging or Microwave Tomography

This technique generates image based on the electrical properties of tissues in human head. The objective of microwave tomography is to obtain dielectric profile of the brain. Human head contains different tissues with larger variations in dielectric properties. The vector network analyzers along with number of transmitting antennas are used for illuminating the target tissue. Matching medium is to be properly chosen to avoid reflection that may happen in the air body interface. The reflections are collected by the receiving antennas surrounded by the target tissue and Scattering coefficients are measured. This can be used for reconstructing the image based on dielectric parameters distribution in the region of interests. It involves solving a non-linear inverse problem to create an image of biological tissue.

B. Qualitative Microwave Imaging or UWB Radar Technique

This technique is used to find qualitative profile to represent the target object. Synthetic aperture radar and ground penetrating radar are the examples of qualitative imaging. In case of tumor detection, this type of imaging gives information about shape and location of target tumor tissue. Synthetic aperture Radar analyses the reflections from the target area to locate the tumor or malignant tissues. It is purely based on the measurement of phase shift from the reflected signal ignoring the amplitude. Dielectric properties cannot be measured by this method.

C. Vivaldi antenna Design and analysis

Micro strip antennas are mainly preferred for near field imaging because of low cost and high gain [12]. Vivaldi antenna radiates or receives UWB pulses without distortion, good directivity, and a high efficiency. In this paper, Vivaldi antenna is designed and simulated using CST microwave studio software (2020 version). The frequency ranges of this antenna are in the UWB region and resonate at 3.5GHz and 2.2GHz. This antenna is designed on an FR-4 substrate material having 1.6 mm thickness and dielectric constant 4.3 as shown in Figure2.

Figure 2. Structure of Vivaldi antenna

Vivaldi antenna is good for transmitting a pulsed signal over a broad frequency spectrum. The design equations are shown below.

$$L = W = \frac{c}{fo}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

$$W_2 = \frac{120\pi}{\sqrt{\varepsilon_r}}\frac{h}{z_0} \quad (2)$$

$$y=C\, e^{rx} \quad (3)$$

$$y=C\, e^{-rx} \quad (4)$$

The exponential arms are calculated using the equation (5), (6), (7) and (8)

$$R_1 = \frac{W_1}{2} + \frac{W_2}{2} \quad (5)$$

$$R_1 = \frac{W_1}{2} - \frac{W_2}{2} \quad (6)$$

$$R_{s1} = W_1 = L \quad (7)$$

$$R_{s2} = \frac{R_2}{2} \quad (8)$$

IV. SIMULATION RESULTS AND DISCUSSION

The antenna is simulated in CST microwave studio and various parameters are analyzed. It provides s_{11} value below -10dB over a specified frequency range. The Figure 3 shows the recording of s_{11} value equal to -40 and -43.79 at two resonance frequencies 2.2GHz and 3.5GHz respectively. This is due to perfect matching of patch and ground plane. The far-field pattern at 2.2GHz and 3.5GHz are represented in Figure 4 and Figure 5 for an angle of 90°. The far-field pattern indicates high gain and directivity of 8.7 dBi for Vivaldi antenna with circular shaped parasitic patch.

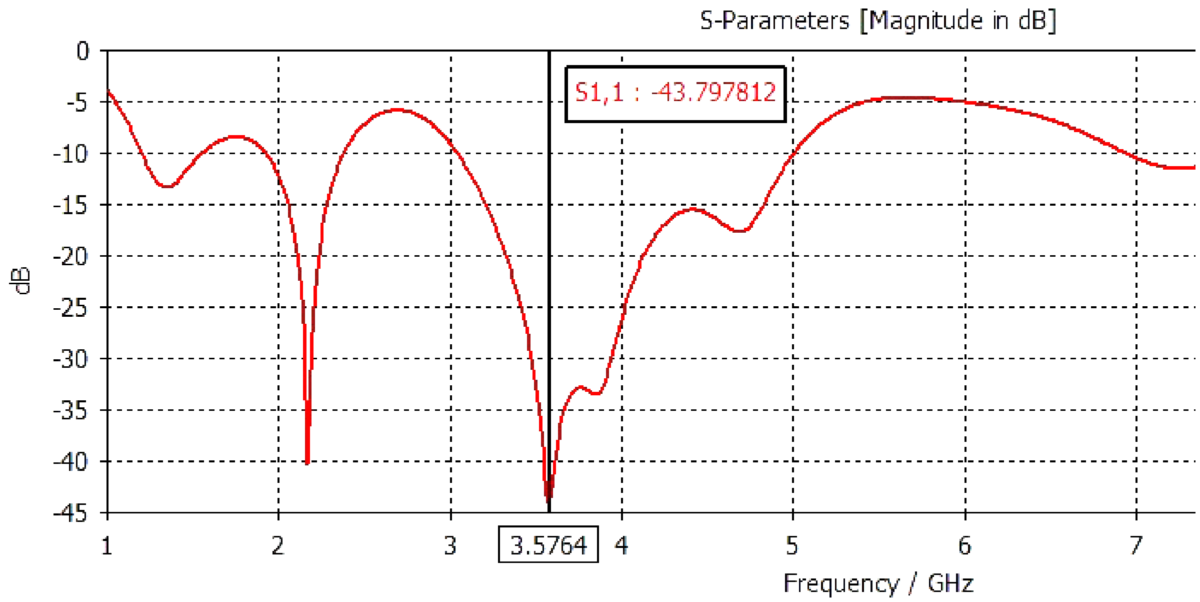

Figure 3. The S-parameter curve of the designed antenna

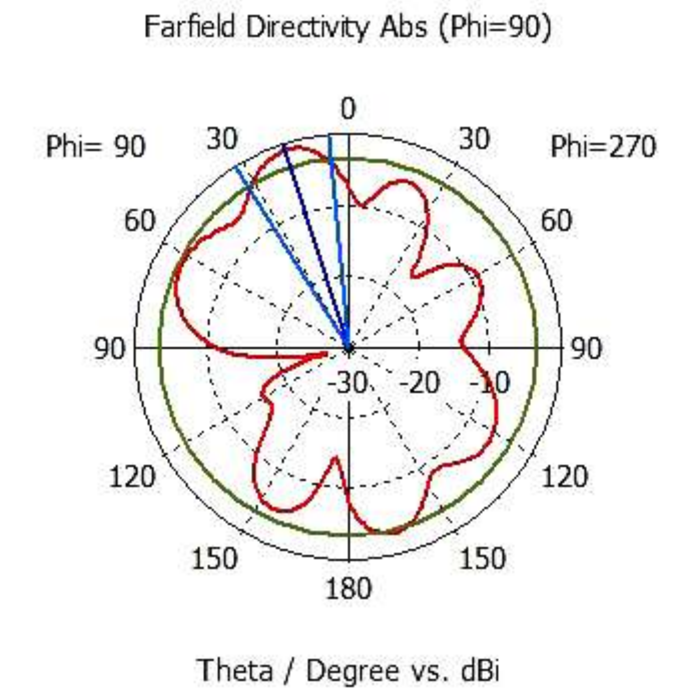

Figure 4. The Radiation pattern and directivity at 2.2 GHz

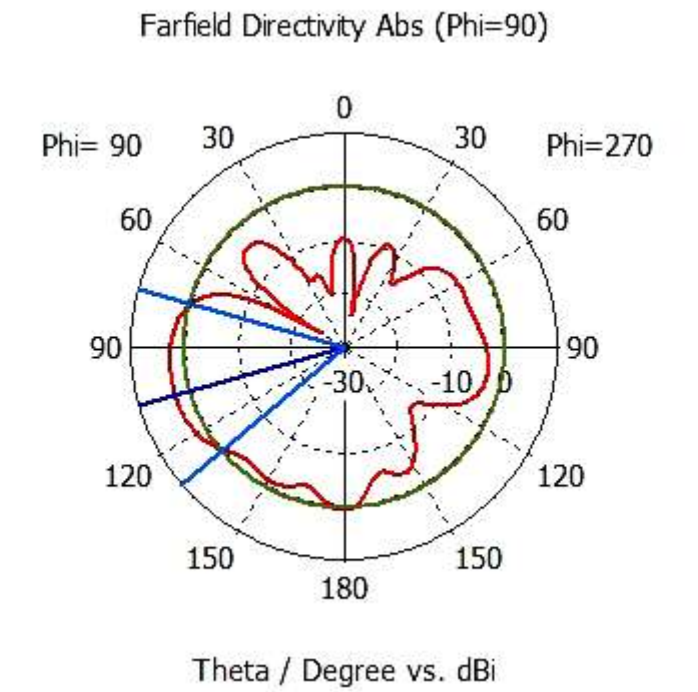

Figure 5. The Radiation pattern and directivity at 3.5 GHz

The simulation of an antenna with head phantom is done with the properties mentioned in Table 1. The dielectric permittivity values of each tissue is calculated according to Federal Communications Commission database .The created phantom design shown in Figure 6 is simulated in CST microwave studio at two resonance frequencies. It has been observed that blood clot/stroke is identified by high reflection (Table 2).

Table 1. Dielectric Properties of different head tissues

	Skin	Skull	Gray matter	White matter	Stroke
Permittivity	46	12.4	52.3	38.6	61
Conductivity(S/m)	0.88	0.155	0.98	0.62	2

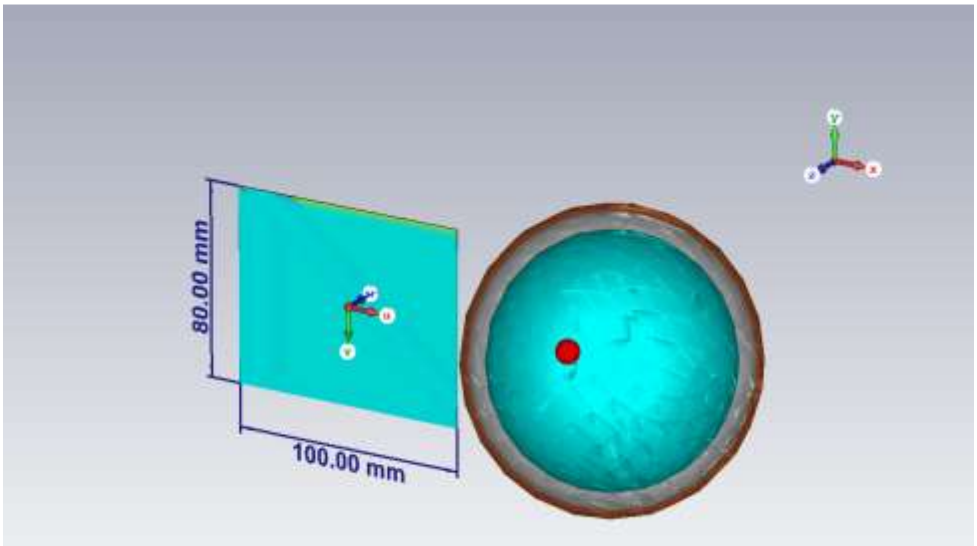

Figure 6. The Vivaldi antenna with head phantom simulation

Table 2. Calculation of Reflection coefficient with and without Stroke

Diameter of the stroke (mm)	Frequency in GHz	Reflection coefficient of antenna in dB	
		With Blood clot	Without Stroke
10	2.2	-10.9	-13.4
	3.5	-10	-12.9
15	2.2	-10.4	-12.9
	3.5	-10.5	11.85

This radar imaging results in portable and alternate imaging technique for Human head. This proposed system utilizes novel qualitative imaging technique for detection of stroke with minimum blood clot size of 10 mm. The performance of various stroke detection systems are compared in table 3 and the simulation result of proposed radar technique shows better accuracy.

Table 3. Performance Comparison Chart

Reference	Antenna Type	Algorithm used	Frequency of operation	Nature of work	Dynamic range/Gain
[5]	24 Monopole antennas	Truncated SVD based algorithm	1 GHz	Experimental Verification	40 dB
[8]	Computer simulation and antenna type not mentioned	Newton approach	0.5–2.5 GHz	Simulation done	Low dynamic range

[9]	Log periodic static antenna array	Confocal DMAS algorithm	0.85-2 GHz	Simulation done	6.2 dB and the smallest imaging area is taken as 2 cm radius.
[11]	Flexible antenna array	Confocal imaging algorithm	1.45 GHz	Experimental Verification with SAM head model	3.5 dB
[12]	Microstrip patch antenna	Radar technique	3.1 GHz to 10.6 GHz	Antenna design	6.4 dB
Proposed work	Vivaldi antenna	Radar Technique	3.1 GHz to 10.6 GHz	Antenna design and Location of Blood clot from reflection	8.7 dB and Blood/clot of size 15 mm and 10 mm radius can be detected

V. CONCLUSION

Microwave imaging of Human head is really challenging, and proper choice of frequency is essential. It is suggested to use 1-4GHz for head imaging, the choice of coupling Media is another criterion, and it can be overcome by hybrid imaging. Quantum optical sensing can be used to reduce the loss incurred in the transmission media. Microwaves are not only the diagnotisic tool and it is also a therapeutic (hyperthermia, thermo- ablation) for treatment as well as continuous monitoring of patients.

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