UWB Slotted Circular Disc Monopole Antenna with Inverted U Shaped Defected Ground Plane for Brain Cancer Detection

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ABSTRACT

In this paper the new design of UWB inscribed slotted circular disc monopole antenna is used in the detection of brain cancer is presented. The proposed antenna design consists of circular patch and the bandwidth is increased to cover the UWB frequency range of 3.2 GHZ to 10.6GHZ by embedding square shaped slot cut at the centre and a pair of inverted U shaped cut in the ground plane which gives a defected ground structure that provides the fractional bandwidth more than 110%[3.2 -10.6GHZ]. The proposed antenna is designed and fabricated for brain cancer detection. FR4 substrate is used with printed circular monopole radius of 15mm and with finite ground plane of (60mm x 50mm). It is designed with thick substrate with the thickness of h=1.6mm and high dielectric constant of ε_r=4.4. The voltage standing wave ratio is of (1-1.5). The proposed antenna design provides minimum return loss, better fractional bandwidth, satisfactorily radiation pattern.

Indexing terms/Keywords

UWB monopole antenna, fractional bandwidth, brain cancer detection

1.INTRODUCTION

Cancer is one of the major disease which affects the millions of people, that leads to death. Early detection of cancer is done by using clinical diagnostic methods like X-rays, mammography, MRI and ultrasound technique which is high cost and high reliability. These methods have some limitations in diagnosing the cancer cells correctly. Radar based UWB microwave imaging method is low cost with non- invasive method of detecting the differences in cancer cells with surrounding tissues based on their electrical properties. Microwave imaging systems require UWB antennas , which is in the definition of FCC. Since, the UWB has wide spectrum. The main characteristics of developing the low cost UWB systems can be applied commercial and military applications.UWB microwave imaging is a technique which is used for biomedical applications such as cancer detection. The transmitting and receiving antennas with a suitable UWB antenna is capable of working over an ultra wide bandwidth which is allotted by Federal Communications Commission for the UWB range frequency of 3.1 -10.6GHz. Efficiency, good radiation properties with perfect time domain performance is the major requirement of UWB antenna.[1-3]. The ground plane is majorly concentrates on impedance matching circuit . The width of the ground plane and radius of the circular patch effects the bandwidth characteristics. The circular monopole antenna depicts the UWB performance for the detection of brain cancer[4]. ultra-wideband vivaldi antennas is designed and it is placed with the a brain model with 4 layers with the radius of 5mm tumour model is designed and the electromagnetic short pulse can be transmitted into the simulated brain phantom model and the reflected signals are analysed for brain cancer detection[5]. Miniaturized microstrip antenna with T shape and U shape slot is designed and simulated to achieve the requirements of UWB characteristics with wide bandwidth and better reflection coefficient [6-7].For the wide fractional bandwidth two inverted U shaped slots and two L shaped slots were inserted at the either side of the substrate for wide impedance bandwidth[8]. The different types of monopole antennas can be used for UWB applications, circular patch monopole is one of the antenna which can be used for medical applications for wide frequency bandwidth and gain flatness over the frequency range[9].The microwave imaging techniques needs antennas which will work for both single and multi range frequencies. This multi- frequency techniques can be used in deeper penetration into the human body for detection of stroke[13,14].The dielectric properties of a human tissues over the ten decades and evaluation and analysis of the dielectric tissues for the measurement are described in the graphical format[19]. The dielectric properties of human tissues in the frequency range of 10Hz to 100GHz and its properties are examined and its results from the interaction of electromagnetic radiation along with its constituents at both cellular and molecular level. [21-22].

2. ANTENNA STRUCTURE AND PRINCIPLE

2.1 Antenna geometry of the UWB Circular monopole antenna

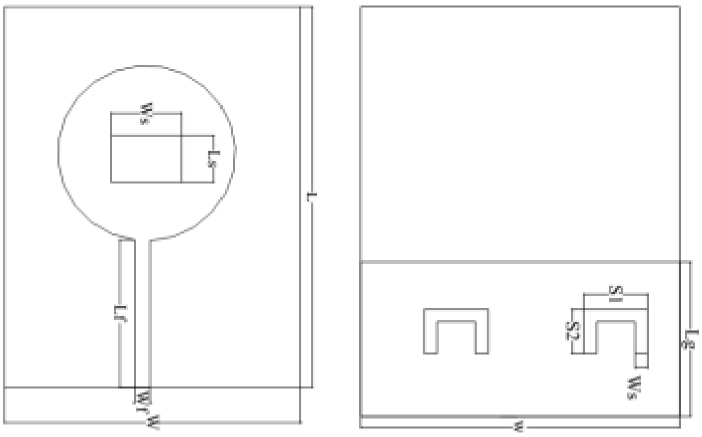
The circular shape disc is located over the ground plane and it is called monopole antenna. The basic configuration of circular disc monopole antenna is designed for the 65 x 50 x 1.6mm ^{3} , which has FR4 substrate with the thickness of 1.6mm and dielectric constant of 4.4. The circular monopole antenna is designed with the radius r of 11mm and the circular disc is mounted on a partial ground plane on the other side of the substrate with the length of 11mm. The simulated result produced for UWB's frequency range under the has return loss less than -10dB from 3GHz to 10.6GHZ. The resonated frequency has wide bandwidth. The dimensions of the basic antenna is shown in table 1.

Table 1: **Geometry of the basic circular monopole antenna**

Parameters	Dimension(mm)
W	65
L	50
Radius	11
L_g	24.5
L_f	37
W_f	1.6

2.2 Design of modified UWB slotted circular monopole antenna

As we are familiar that wide range of slot antenna in UWB frequency range can provide wider fractional bandwidth and size limited for wideband applications. The structure of the UWB slotted antenna design is shown in fig 1. The proposed design is responsible for detecting the tumour in the human brain in the UWB frequency range. This antenna is printed on FR4 substrate with the thickness of 1.6mm. The square slot at the length and width Ls and Ws. The center of the circular monopole antenna has low current density and if that area is removed it will not affect the surface current[24]. The number of slots is increases, the energy radiation out of the antenna gets increases. And therefore in this one 12 x8 mm ^{2}, square slot is designed at the center to get the better return loss. Generally for the circular disc monopole antenna, ground plane is used for impedance matching circuit. It tunes the input impedance by changing the length of the ground plane. Defected Ground Structure[DGS] is designed using two small U slot which is inserted in the partial ground plane in order to increase the operational bandwidth of the circular monopole antenna with microstrip feed.The dimensions are shown in table 2.The width of the feedline is designed to match the 50Ω matching impedance and also to match the radius of the circular patch. The UWB frequency range from 3.2GHz to 10.6GHz resonation can able to detect the smaller size of the brain tumour . The length and width of the designed antenna is 65x50mm^2.



a. b.

Fig.1 Proposed Circular monopole antenna
a.square slot at the circular patch
b.defected ground structure in the ground plane

Table 2: Geometry of the UWB modified circular monopole antenna

Parameters	Dimension(mm)
W	65
L	50
Radius	11
L_g	24.5
L_f	37
W_f	1.6
W_s	12
L_S	8
S_1	10
S_2	5
W_s	2

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2.3 Design of circular monopole antenna

The design expression for the circular monopole antenna for calculating the resonant frequency [23] is given as

$$f_r = \frac{1.841 v_0}{2\pi r_{eff}\sqrt{\varepsilon_{eff}}} \quad (1)$$

where, v0 is velocity of light in free space, The fr is the accurate resonance frequency in the circular microstrip antenna which has taken in to account for the fringe fields effects and the total loss of dielectric loss, conductor loss, feed loss, surface-wave loss and radiation loss.The effective radius reff is

$$a = \frac{F}{\{1+\frac{2h}{\pi\varepsilon_r F}[\ln(\frac{\pi F}{2h})+1.7726]\}} \quad (2)$$

The directivity of the circular microstrip antenna is given in terms of function parameter γ is given as

$$D(\gamma) = 4.77142 - 0.12087\gamma + 2.98537\gamma 2 - 1.25954\gamma 3 + 1.25337\gamma 4 - 0.50481\gamma 5 dB \quad (3)$$

By this expression the circular monopole antenna is designed and the dimension of the designed antenna is shown in table 2. The advantage of using slot in the patch for increasing the bandwidth in the microwave imaging.

2.4 Characteristics of modified UWB antenna

The clear understanding of the proposed antenna is mainly based on analyzing the current distribution of the antenna that concentrates along the circumference of the circular disc. The current density is lower at the middle section of the circular disc monopole antenna. Hence, the current will not effect if the middle part of the circular disc monopole antenna is removed. By this manner, the effective path of the surface current will retains longer. In this paper, the square slot is inscribed at the centre of the monopole antenna for increasing the bandwidth without disturbing the current distribution and it is shown in Fig. 1. The 50 Ωimpedance is achieved by adjusting the width of the feed W = 1.6mm and the ground length has been optimized to L_g =24.5mm in order to achieve the UWB characteristic for microwave imaging in brain tumour detection. The build antenna is connected 50Ω SMA connector and measured using Vector Network Analyzer.Parametric study of circular monopole antenna: The parametric values with its dimensions of the optimized circular monopole antenna shown in table 2.

2.5 Effect of Length of the ground plane

The ground plane is used as an impedance matching circuit and therefore it can be used in tuning to the resonant frequencies. The -10dB simulation result for the operating bandwidth of the antenna is based on the length of the ground. The return loss curve for the different width of the ground plane is taken for the radius of the circular patch of r = 11mm, ground length Lg=24.5mm and the feed gap h=1.6mm is shown in figure 2.The length of the ground plane should be around λ/4 or it is equivalent to diameter of the circular patch. It can be seen that -10dB operating bandwidth is increases gently with Lg being reduced from 34.5mm to 24.5mm, and the bandwidth for an antenna is between the range of 3GHz to 10.6GHz. by the optimized value of Lg=24.5mm. This result is clearly demonstrates that the operating bandwidth of the antenna is highly dependent on the ground plane.

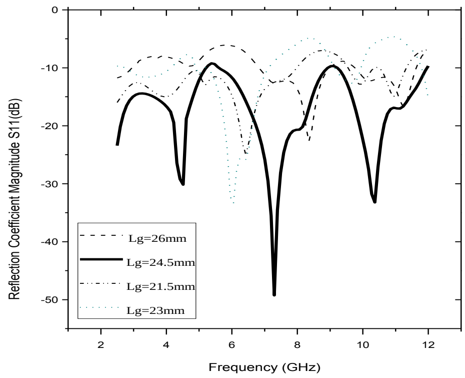


Fig 2.Simulated results of proposed antenna for various length of the ground plane

2.6 Effect of radius of the circular patch

The diameter of the circular patch reveals the effect in the resonant frequency. The dimensional changes in the diameter of the patch has been simulated for the values between 11mm to 17mm, the simulated result is shown in fig 3.

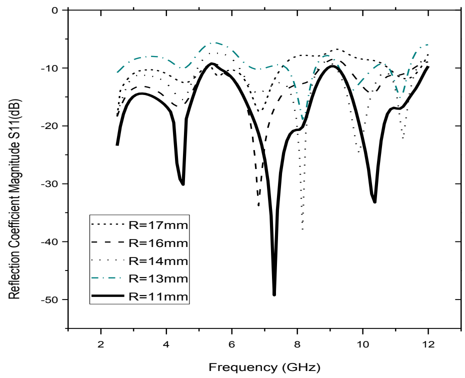


Fig 3.Simulated results of proposed antenna for various radius of the circular patch.

2.7 Effect of Defected ground structure

The defect in a ground is used to reduce the antenna size . Antenna size is reduced for a particular frequency as compared to the antenna size without the defect in the ground. DGS is realized by introducing a shape defected on a ground plane thus will disturb the shielded current distribution depending on the shape of defect .The input impedance is influenced by the disturbance at the shielded current distribution and the current flow of the antenna.

3. RESULTS AND DISCUSSIONS

In the parametric study of various parameters of ground plane, feed line width and the diameter of the circular patch were optimized using HFSS software, and the proposed antenna are adjusted according to the optimized results and values are shown in table2.The UWB antenna which corresponds to the proposed antenna design with various slots at the patch and ground plane for early detection of the malign tumor in the human brain The basic design can provide with lower resonant frequency, but with modified proposed structures, the bandwidth level is improved with lower and higher resonant frequencies for 2.5GHz,4.5GHz,7.5GHz and 10.5GHz are excited. The VSWR of the antenna is simulated in HFSS and the result is less than 2, which is sufficient to cover the uwb band provided by FCC is presented in figure 4 and the 3D radiation pattern for the frequency 2.5GHZ is illustrated in figure 5.

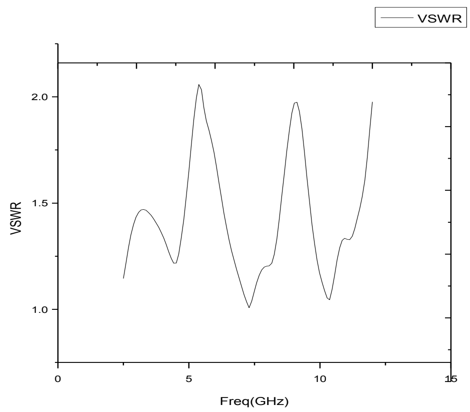


Fig 4.VSWR results for the proposed antenna

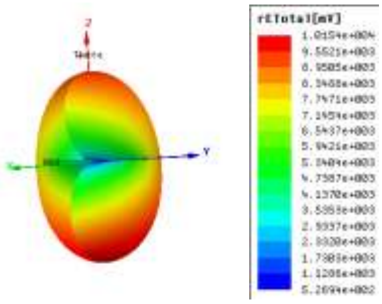
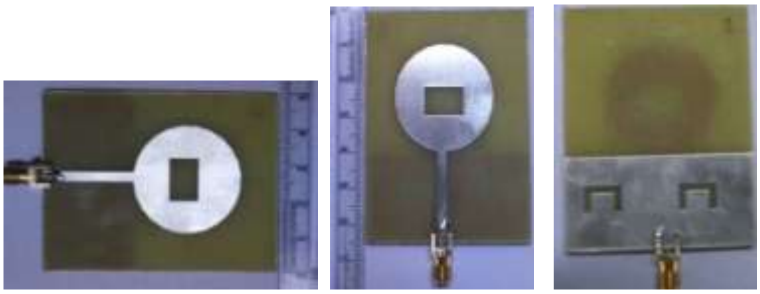


Fig 5: 3D radiation pattern



a b c

Fig 6: a,b&c Fabricated proposed circular monopole antenna patch

The bandwidth is measured at -10db ranges between 2.5 GHz to 12.5GHz. The width presented as 24.5mm, and therefore the fractional bandwidth is calculated as 118%.To evaluate the performance of the optimized antenna, the proposed modified circular patch antenna is fabricated and tested. In order to compare the simulation results of the antenna, the proposed antenna with square slot at the center of the patch and inverted U slot in the ground plane is manufactured and tested using vector network analyzer. The measured and simulated results of return loss is compared and it is shown in fig 8, then the changes in the measured results due some errors in the manufactured antenna and SMA connector in the feed line.

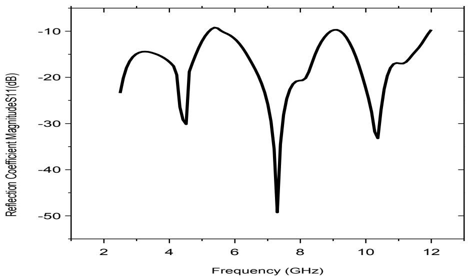


Fig 7.Simulated result of proposed antenna with respect to return loss

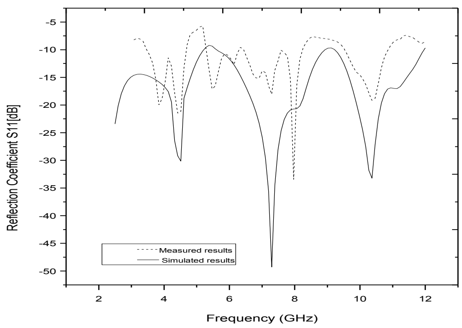


Fig 8.Measured and simulated return loss results of the proposed antenna

Figure 9 depicts the simulated radiation pattern which includes the co-polarization and cross- polarization of H-plane(x-z plane) and E-plane(y-z plane) for various frequencies.It shows that the omni directional radiation pattern is observed in x-z plane.With the increase in frequency, radiation pattern become worse because of the change in the cross polarization.

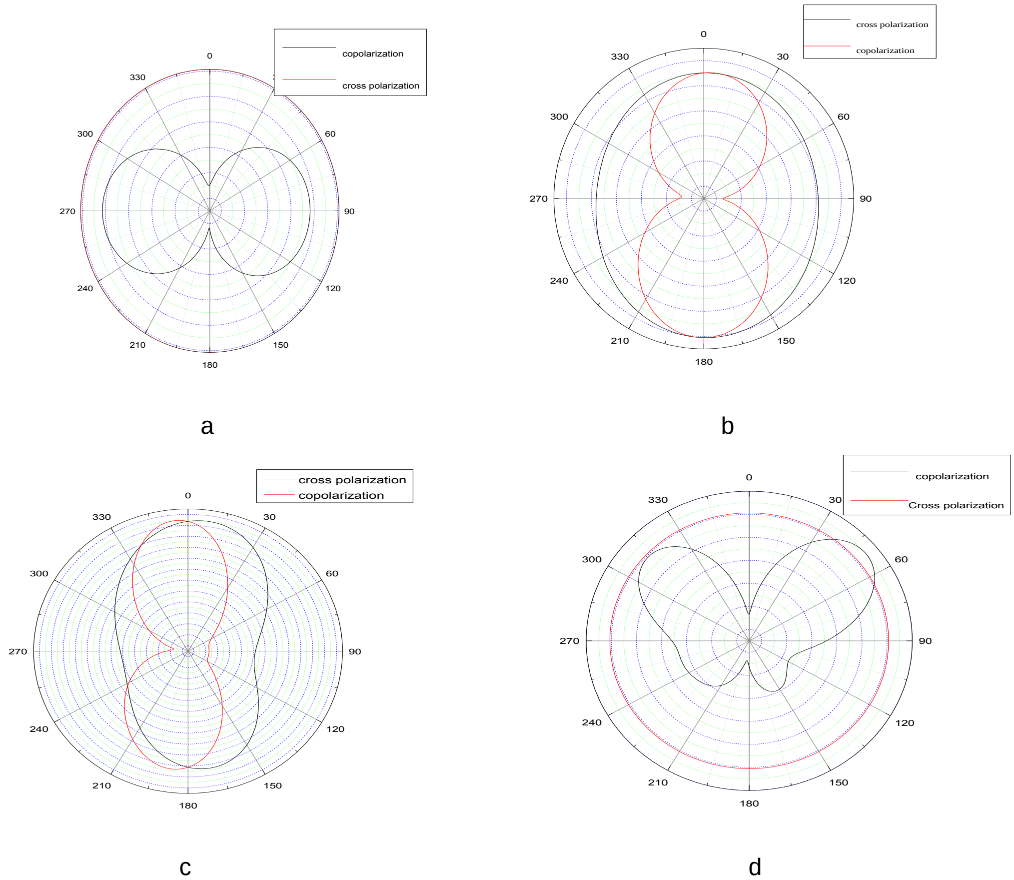


Fig 9:a&b Radiation pattern for H-plane and E-plane in the frequency 2.5GHz,
c&d Radiation pattern for H-plane and E-plane in the frequency 4.5GHz

3.CONCLUSION

This UWB slotted circular monopole antenna has gives the following results: better return loss, improved bandwidth, low VSWR compared to circular monopole antenna. These fundamental parameters are simulated using HFSS software. The effects of defected ground structure and slots in the patch has been successfully verified by comparing with measured and simulated results. This improved results can be used in the early detection of human brain cancer.

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