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Compact Slot Loaded Dipole Antenna For Intracranial Hemorrhage Detection

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Abstract

Microwave head imaging systems necessitate compact antennas with steering radiation. To realize the antenna solidity, the sharing technique based on image theory has been used. This halving technique causes a tilt in the main-beam direction. To avoid this, the lateral feeding technique can be used to antenna with the potential to preserve their beam direction. By this technique, the compactness can be achieved. The essential mechanism behind the beam correction is analyzed. The overall dimensions of the designed antenna is $0.25 \times 0.06 \times 0.06\ \lambda_0^3$ .The measured near and far field radiation patterns validate the unidirectional radiation of the antenna with a stable boresight main beam. Moreover, the designed antennas will meet the optimally attainable solutions. The application of the designed antenna is achieved in robotic microwave head imaging system.

Keywords: Slot loaded, folded dipole antenna, head imaging system.

INTRODUCTION

In current times, microwave imaging techniques have gained a huge interest in medical applications because of their low cost, noninvasive and non- ionization properties [1]. Traumatic brain injuries (TBI) are the leading cause for many disabilities [2].TBI causes intracranial bleeding , which is caused by a blow, fall, or rapid movement of head or by the burst of arteries inside the brain that results in the accumulation of bleeding in a part of the brain [2]. While the current imaging systems, such as MRI or CT scan, are accurate, they are not available outside of the hospital environment due to their bulky and static structure. These systems demand wideband compact antennas with directional radiations for efficient data acquisition [3]. The scattered signals from the forward direction are collected without the signals from the backward direction being interfered which ensures directionality. The benefits of compact antennas are obvious. The compact size of the antennas requires less space as they are an added advantage. They can allocate more sensing elements inside a fixed amount of space to gather more information about the target location. Nevertheless, compact antennas have a more confined phase center, which consequently improves pulse fidelity. Matching of the antennas at high characteristic impedances, increases feeding complexities [4, 5]. Recently, a miniaturizing technique based on magnetic symmetry has been proposed to attain a halved version of a three-dimensional folded antenna [6, 7]. However, the direction of the main beam shifts from the boresight direction due to this modification [8]. This journal describes how the side-feeding technique of a symmetrical antenna can be applied to cross-feed a half-cut antenna in order to correct the radiation performance. The cross -feeding techniques are used which shows the current distributions, impedance matching, and near-field performance, and the mechanism of cross-feeding technique is also demonstrated. The prototyped half-cut slot-loaded folded dipole antenna maintains its main-beam radiation at the boresight direction in both near and far fields. The antenna is applied in an automated head imaging system, and the reconstructed results demonstrate suitability of the wideband directional antenna for such applications.

ANTENNA GEOMETRY AND DESIGN

The antenna is designed on a two low loss substrate called Roggers4350B slabs with permittivity ε_r =3.0, loss tangent tan δ = 0.003, and thickness h = 1.52 mm. The top slab is printed double-sided, and the antenna is fed at the top layer with a 50-Ω microstrip line. The bottom layer is printed as a rotated mirror image and connected to the top slab along x- axis.

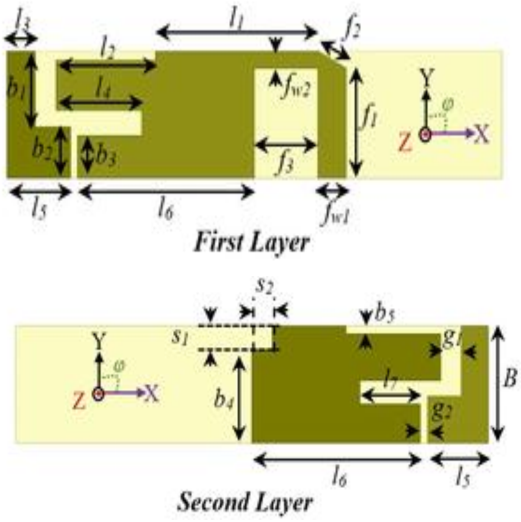

Figure 1: Schematic diagrams of the proposed antenna

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The antenna is replicated from the conventional slot-loaded folded dipole antenna. It is consequently halved using the modified halving and feeding technique based on the theory of magnetic symmetry of the radiating structure [7, 9]. However, it is found that most of the full-sized antennas are center-fed. As a result, the half-cut antennas become side-fed after miniaturization. The existing side feeding technique [1], which is utilized to simplify the center excitation mechanism, turns the half-cut antenna into cross-fed with the potential to correct the radiation beam. To understand the underlying mechanism, both types of feeding techniques need to be analyzed.

Although radiation patterns of both E- and H-planes are affected, it is noted that the inclination can be observed vividly from the H-plane radiation perspective. In full-sized antenna, the currents of the feeding line are not significant, as the currents are distributed over a big surface. The direct-feeding technique in the proposed half-sized antenna increases the current distribution at the opposite part of the excitation end [10]. As a result, the tilted radiation beam due to the one-sided excitation current, reported for halved antennas is balanced. In addition to the adjustment of the radiation patterns, the cross-feeding technique reduces the input resistance and increases the capacitive reactance by reducing the feeding line distance and meandering process.

The optimum design dimensions of the proposed antenna are (in mm): L = 70, W = 15, h = 1.590, l1 = 14, l2 = 11, l3 = 9, l4 = 25, l5 = 5, w1 = 9, w2 = 6, w3 = 3, f1 = 22, f2 = 4, f3 = 2, f4 = 2. Eventually, the impedance matching of the antenna is enhanced, and the highest operating frequency of the antenna is increased from 2.6 to 3.4 GHz. The simulated optimized design covers 2.4–3.5 GHz which is the band used for microwave head imaging as a compromise between the required signal penetration in the head and image resolution [11]. The operating principle of the proposed halved antenna remains the same as the conventional slot-loaded antenna [12]. Nevertheless, the unidirectional radiation of the antenna is dependent on the high concentration of surface currents on the top slab and reflection from the bottom slab.

ANTENNA PERFORMANCE

The performance of the proposed antenna is verified through measurements. As seen from Fig. 2 the measured reflection coefficient closely matches the simulated one. The prototyped antenna covers a wide bandwidth of 2.4–3.5 GHz, with respect to the center frequency of 2.9 GHz. There are some discrepancies between the simulated and measured results due to the fabrication process of the prototype.

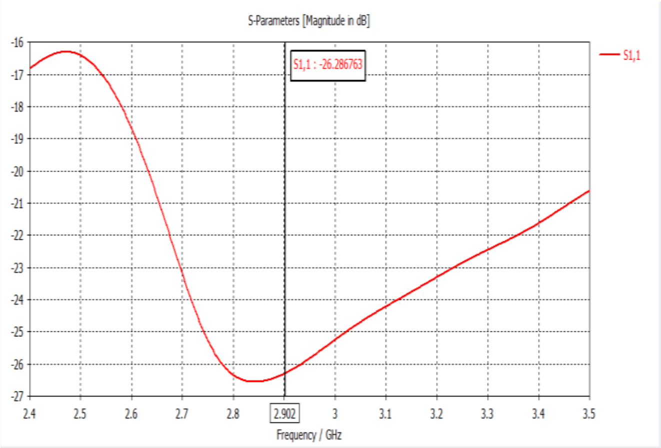

Figure 2: Reflection coeefficient of slot-loaded dipole antenna

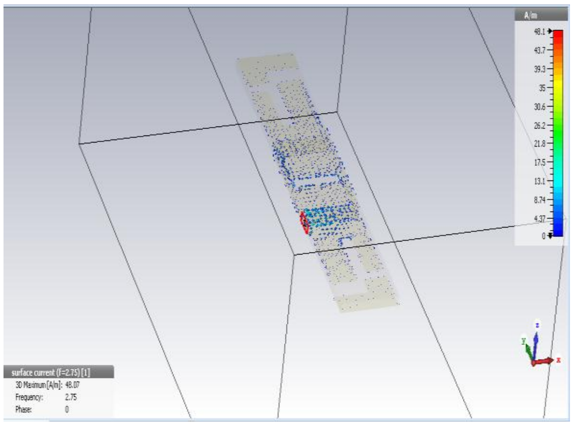

Figure 3: Current distribution of the proposed antenna

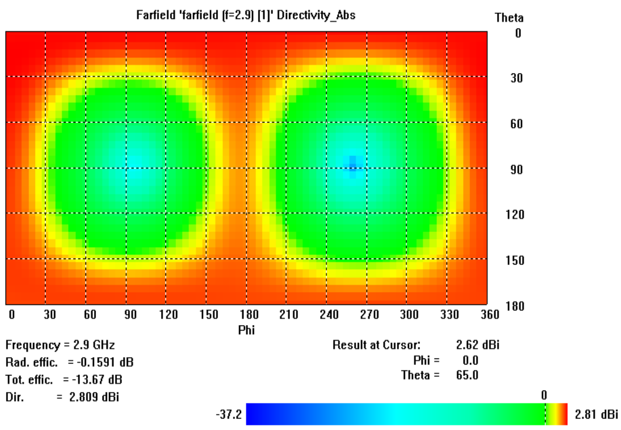

Figure 4: 2D far field radiation pattern at frequency 2.9 GHz

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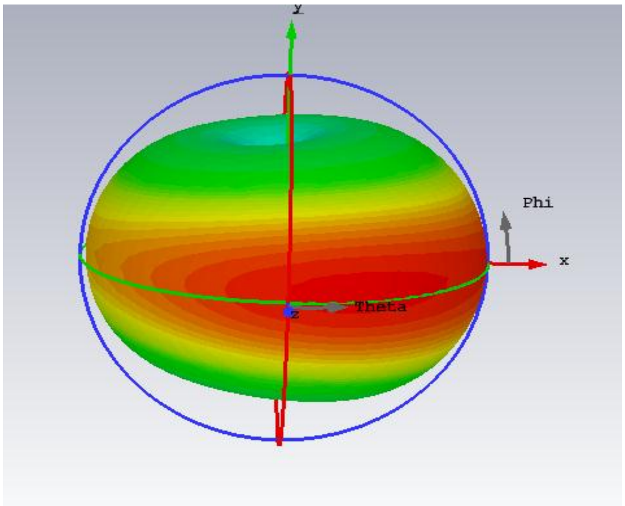

Figure 5: 3D view of far field radiation pattern at 2.9 GHz

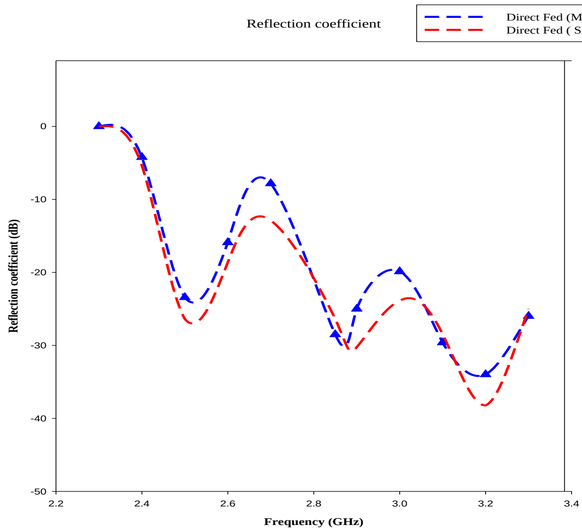

Figure 8: Comparison of reflection co-efficient of the antenna

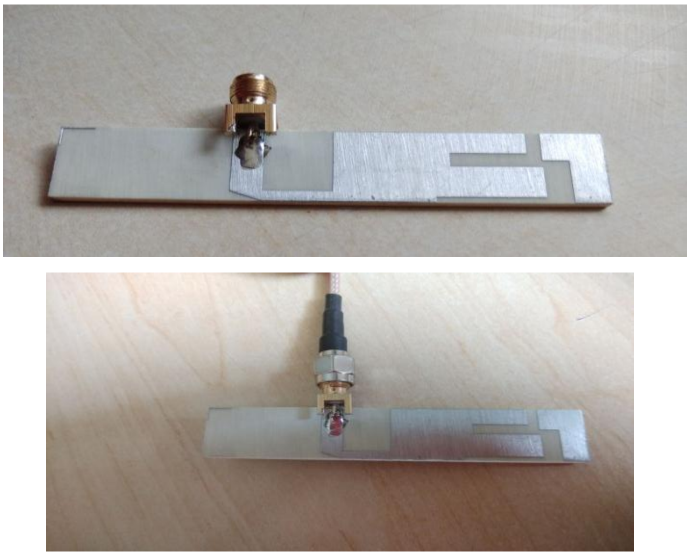

Figure 6: Prototype of the slot-loaded dipole antenna

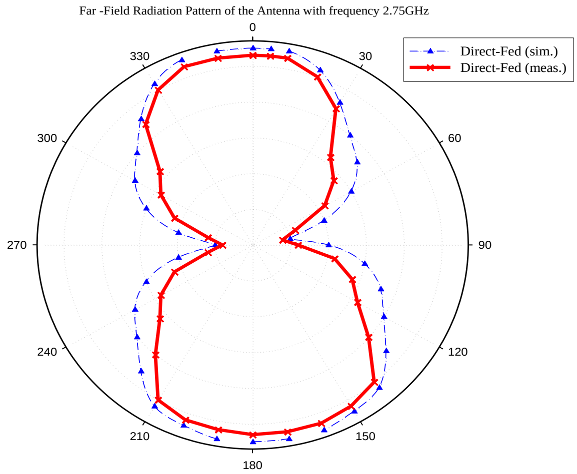

Figure 9: Radiation pattern of the antenna at frequency =2.75 GHz

Figure 7: Slot-loaded dipole antenna connected with the VNA

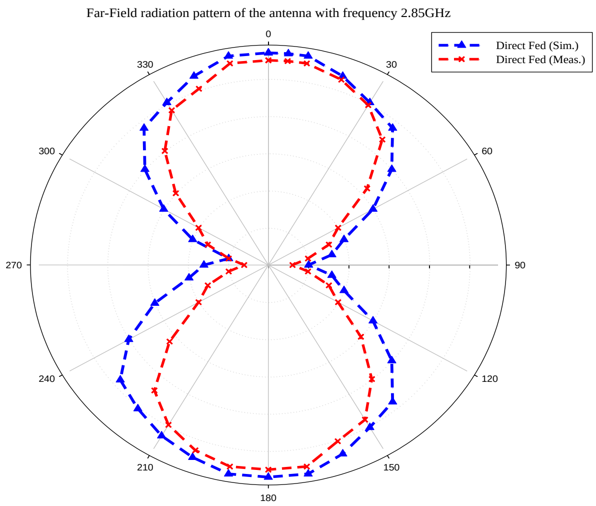

Figure 10: Radiation pattern of the antenna at frequency 2.85 GHz

Due to high permittivity of the human head, the antenna might also need to operate in the far field. For this reason the far field radiation patterns of the antenna are measured which is shown in Fig 9 an average gain of round 3dBi is found over the operating band along the bore sight direction. We use an anechoic chamber to measure the near and far field radiation pattern. Its near-field radiation performance is important as the antenna is placed close to the head imaging system and, thus, measured by using a near-field wideband probe [13]. The measured far-field performance show that the antenna transmits in a unidirectional manner. This ensures less noise from the unintended backward direction and increases the dynamic range of the scattered signal received from the targeted front direction [14]. The scattered signals are collected together to obtain a sample with high clarity.

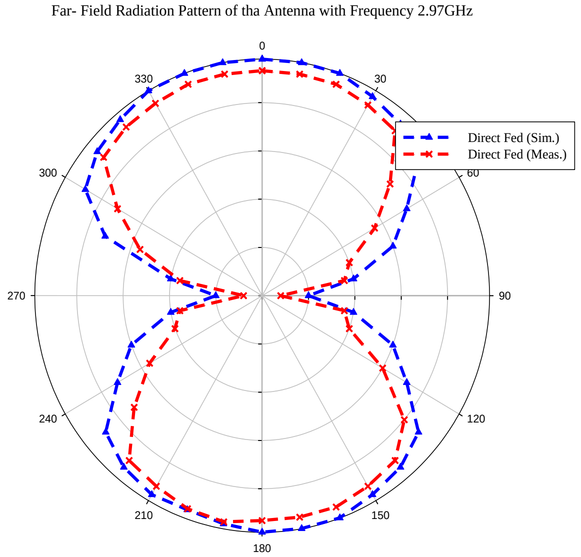

Figure 11: Radiation pattern of the antenna at frequency 2.9 GHz

The increased amount of samples thus helps in a better data acquisition and provides a highly valid data. As a result, the antenna promises fewer artifacts incurred by noise and reduced discrepancies. The cross polarization of the antenna is less than –10 dB along the positive z-direction. Moreover, extended simulations reveal that the antenna attains an average radiation efficiency of 88%. The antenna also provides unidirectional radiation in the far field. Most importantly, the prototype shows that far-field radiation patterns are quasi-symmetrical and the main beam is consistently along the intended z-direction. The field intensities of direct-fed and cross-fed antennas in both planes are comparable to each other. From the center of the antennas in XZ-plane, the field distributions of both antennas look similar.

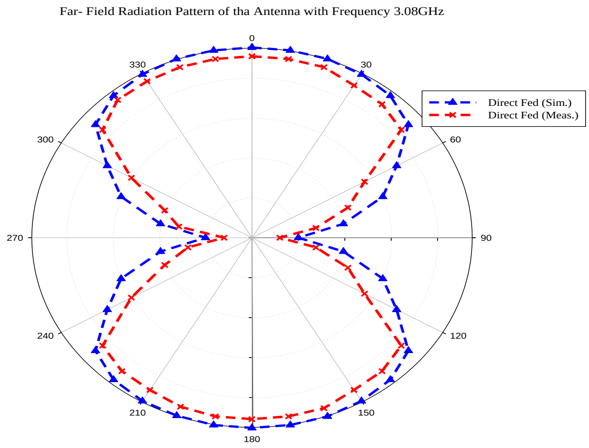

Figure 12: Radiation pattern of the antenna at frequency 3.08 GHz

COMPACTNESS OF THE PROPOSED ANTENNA

The overall size of the proposed antenna is 0.25 × 0.06 × 0.06 λ0 3, where λ_0 is the wavelength at the lowest operating frequency (2.4 GHz). The prototyped antenna is compared with the designed wideband antenna such that the dimensions and bandwidth of the wideband are similar in range [15]. From the concept of fundamental limits of antennas, we can determine how optimum the antenna is toward achieving best performance considering its physical size. Considering the maximum allowable voltage standing wave ratio, s = 1.101.This indicates the optimum design of the antenna is stable and unidirectional [16, 17]. When compared to another optimum antenna it is noted that the prototyped design has a small size along with a wider bandwidth [18].

The voltage standing wave ratio for the prototyped antenna is measured using the vector network analyser which is shown in fig 9.The resonant frequency is obtained at 2.75 GHz which produces low noise[19]The magnitude for the corresponding resonant frequency is -26.28dB which is shown in fig 2.

ICH DETECTION SYSTEM

In an ICH (intracranial hemorrhagic) strokes detection system we use microwave head imaging system to check the affirmed values of the proposed antenna. The antenna is mounted on to the substrate. A bleeding emulating hemorrhagic target, of 2 × 2 × 1 cm^3 volume, is placed inside a human head phantom [20, 21]. Thus we could check the ICH localization. We know that very low powered signals are being radiated by the antenna and the head tissues are lossy, it is not possible to identify the scattering incepted by the bleeding inside the head in the far-field region [22, 23]. So we place the antenna in the near-field region of the antenna. A portable vector network analyzer Key sight N9923A Field Fox is utilized to collect the scattered signals in different angles around the head phantom [24]. The data collection process resembles acquisition from a virtual monostatic antenna array [25, 26]. The collected data is post-processed, and an image of the head interior is reconstructed by using a delay and-sum-based radar-based image reconstruction algorithm. It is seen that increasing the number of samples also increases the clarity of the reconstructed images and enhances ICH target localization [27]. This indicates that an increase in the number of sensing elements when building an array using the proposed compact antenna promises an improved head imaging system for ICH detection.

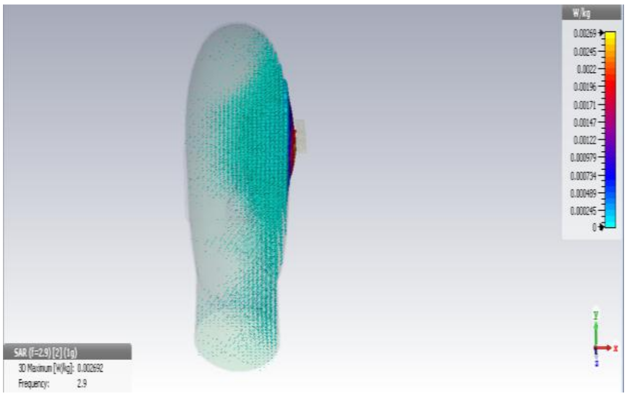

Figure 13a: SAR value at frequency 2.9 GHz

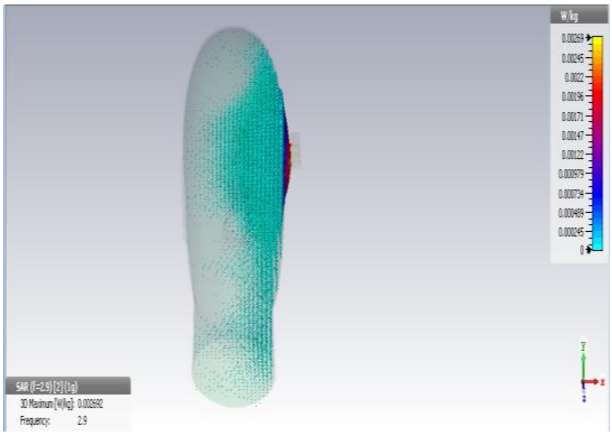

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Figure 13b: shows the SAR value at 3GHz

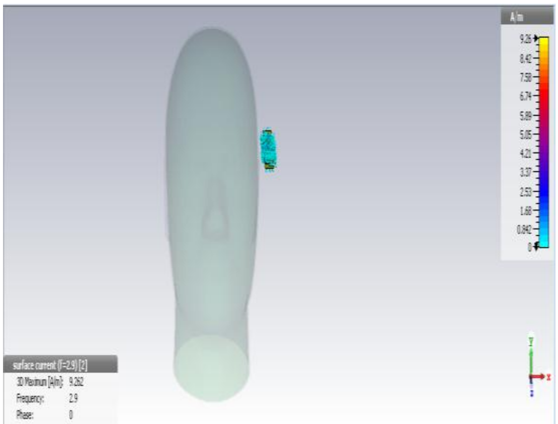

Figure 13c: Surface current at frequency 2.9 GHz

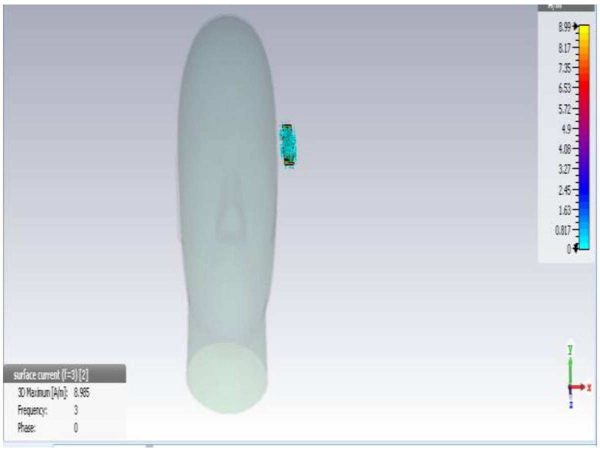

Figure 13d: Surface current at frequency 3 GHz

The calculated maximum SAR over the functional bandwidth of the antennas operating from various direction is depicted in the graph. The antennas transmits the low powered signals and receives the back scattered signals. The specific absorption rate (SAR) is calculated by the CST simulation tool. The head model and .SAR result are presented in figure. It is absorbed that the SAR values are well below the IEEE safety limit of 2W/kg as per safety consideration limits. Since the system might be active over a long time for continuous monitoring of the patient [29]. The thermal effect of the electromagnetic signal is also a matter of interest along with SAR verification. The effect on skin is particularly important as skin absorbs most of the emitted power and heating from 164 the system might cause skin burns or discomfort to the patient.The SAR value as obtained by the designed antenna is 0.002692 at 2.9GHz frequency which is under safety limit and produces low noise over the head.

CONCLUSION

A portable wideband antenna for microwave head imaging has been designed, which is a non-ionizing, low-cost, compact and mobile wideband microwave imaging system that can be applied to monitor the patient continuously in real time, either at the bedside, in ambulance or emergency room for brain injury diagnosis and in doing so makes multiple contributions to the field of microwave imaging systems. The SAR value that is obtained from the simulated prototype is 0.00269W/kg and the maximum point of the attainable SAR is 0.0756W/kg .The background and underlying motivation of this work highlights the necessities for utilizing wideband microwave imaging system for brain injury diagnosis. A compact head imaging system with automated scanning capabilities is also presented. It is observed that imaging improvements can be achieved when the surface waves are considered in image reconstruction. There is less amount of loss as the VSWR value is 1.101 which is a desirable value. The automated scanning system is able to reliably image the interior of human head and it is found that the system is safe from electromagnetic radiation. It is seen that the head imaging system is able to locate brain injuries in various 3D positions of human head. The imaging system is found safe from electromagnetic radiation by maintaining SAR values well below the radiation safety limit.

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