Design of a wideband Unidirectional Antenna for Microwave Head Imaging System

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***Abstract*—Head imaging system requires the antenna with low profile structure having directional radiation pattern and lower operating frequency range. The essential features like wide bandwidth, reduced dimension, and unidirectional radiation characterize the microwave imaging (MI) systems for biomedical applications. The article reports the design of a compact microstrip antenna and analysis with an operating frequency from 2.46 GHz-3.30 GHz. The lower frequency range satisfies the requirement of proper signal penetration into the human head. The antenna provides the radiation efficiency more than 84%. The proposed design covers 29.16% of fractional bandwidth with considerable radiation characteristics. The dimension of the designed antenna is $0.58\lambda \times 0.49\lambda \times 0.12\lambda$, where λ represents the wavelength of the smallest frequency in the required band of operation. This antenna shows stable gain and good radiation efficiency that can be used for biomedical applications in microwave imaging (MI) systems.**

Keywords- Microstrip antenna; microwave imaging; biomedical; head imaging.

I. Introduction

Microwave imaging (MI) systems have a vast application in the biomedical domain where they usually require compact and wideband antennas. This is very much essential in order to acquire efficient data from the above system. The compactness of the antenna is to make portable and deployable system. Along with this, the directional radiation is necessary for the usage of limited power in microwave imaging system.

The detection of the diseases such as brain tumor, breast cancer, brain stroke etc. are basically done by analyzing the scattered signal as a result of the variation of dielectric constant between affected and healthy tissues. The microwave imaging involves satisfactory amount of signal penetration into the human body. This is possible with the lower operating microwave frequencies of antenna. For obtaining this band of interest, varieties of antennas have been reported [1-2]. However, while considering unidirectionality there is limited work done in available designs.

In this article, the design of a compact three-dimensional antenna with wide bandwidth is proposed for the MI systems intended for head imaging application. It has the operating frequency range within the required bandwidth of 1 GHz-4 GHz. With 50 Ω port impedance matching, the antenna eliminates the necessity of a matching network. The design process is explained briefly and the proposed structure achieves an operating bandwidth of 2.46 GHz-3.30 GHz with good front to back ratio and high radiation efficiency value.

II. Antenna Design

The geometry of the proposed work is depicted in Fig. 1. The structure is printed on two blocks of FR4 substrates having $\epsilon_r = 4.4$, and thickness $= 1.6\ mm$. The upper substrate is printed on both the sides with the 50Ω microstrip feed line provided at the top layer. The lower substrate is printed on one side and

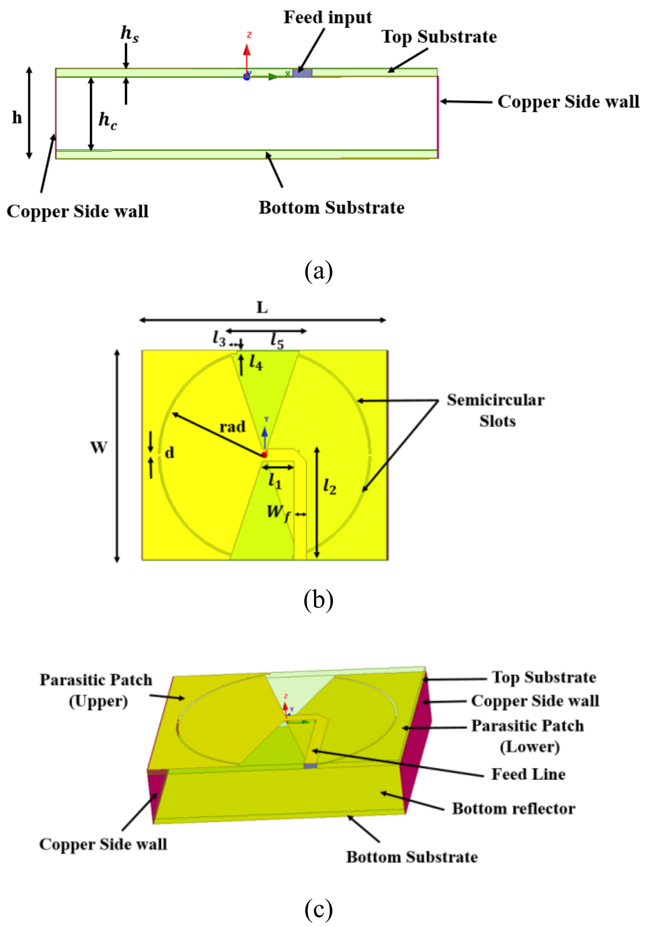

Fig. 1. Structure of the proposed antenna (a) Side view (b) Top view (c) 3D view

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connected to the upper substrate via parasitic copper walls with the height of h. Two bowtie like flares are printed on the upper substrate by cutting triangular slots at both the sides as depicted in Fig. 1 (b). With the aim of increasing the current paths of the antenna two open-ended slots are loaded on the top substrate. Both the substrates are having the same dimension covering the area of $L \times W$. The parasitic structures at the top and bottom side of the upper substrate couples with feed and ground components of the antenna which enhances the effective current path to lower the operating frequency. The construction is similar to a self-grounded dipole. The antenna is designed by using ANSYS HFSS electromagnetic simulation tool and it is fed with a 50 Ω lumped port impedance.

The dimensions of the proposed antenna are calculated according to the following formulae [3].

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \qquad (1)$$

$$L = \frac{\lambda_{eff}}{2} - 2\Delta L = \frac{\lambda_{eff}}{2} - 2 \times h_s \times 0.412\,\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h_s}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h_s}+0.8\right)} \qquad (2)$$

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h_s}{W}\right]^{-\frac{1}{2}} \qquad (3)$$

$$\lambda_{eff} = \frac{c}{f_r\sqrt{\epsilon_{reff}}} \qquad (4)$$

Where f_r, ϵ_{reff}, and λ_{eff} are the resonant frequency, effective permittivity, and the effective wavelength respectively. The final dimensions of the antenna after optimization is shown in Table 1.

TABLE 1. Design Parameters (in mm)

L	W	h	W_F	h_s	d	rad	l_1	l_2	l_3	l_4	l_5
70	60	15	3.5	1.52	1	30	8.5	31.75	3	1	20

III. RESULTS AND DISCUSSION

S_{11} (reflection coefficient) variation of the structure with respect to frequency is shown in Fig. 2. It shows -10 dB bandwidth in the range of 2.46 GHz-3.3 GHz. The plot

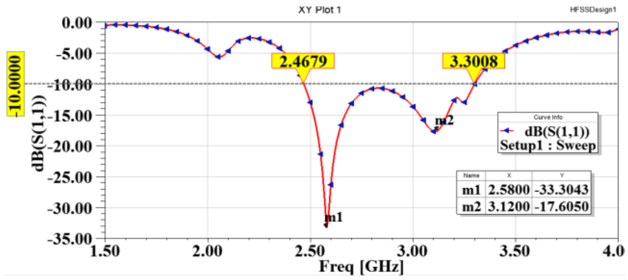

Fig 2. Variation of the Reflection coefficient for the proposed antenna.

represents a fractional bandwidth of 29.16% with the resonant frequency at 2.58 GHz. The peak gain of the design is observed to be 5.43 dB at 3.3 GHz. Fig. 3 represents the variation of gain with frequency for the proposed design. The antenna is observed to be more than 84% efficient throughout the operating band in radiation and is presented in Fig. 4. Fig. 5 shows the radiation patterns obtained at 2.46 GHz, 3.3 GHz, and 2.58 GHz respectively.

The simulation results indicate cross polarization level is below around -12 dB in XZ-plane and YZ-plane at 2.58 GHz.

IV. CONCLUSIONS

A wideband compact antenna has been introduced and analyzed. The three-dimensional antenna is designed using the slotted dipole and the parasitic elements. The low profile antenna covers about 29.16% fractional bandwidth, and efficiency greater than 84% over the frequency band of 2.46 GHz-3.3 GHz. The antenna can be prescribed to be used in microwave imaging systems for biomedical applications due to its lower operating frequency range.

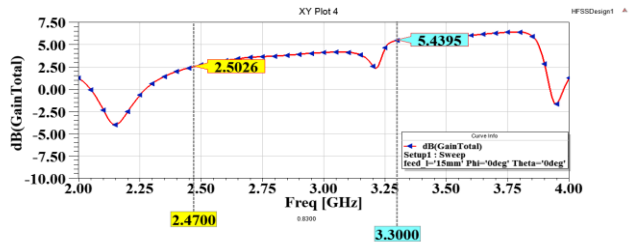

Fig. 3. Variation of gain for the proposed antenna.

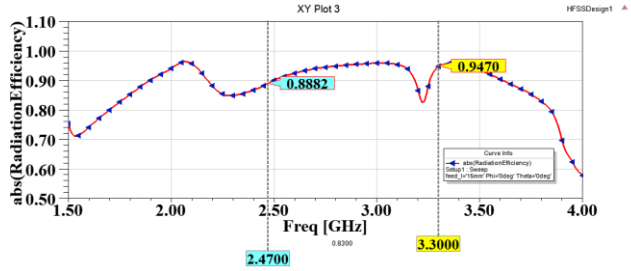

Fig. 4. Variation of radiation efficiency for the proposed antenna.

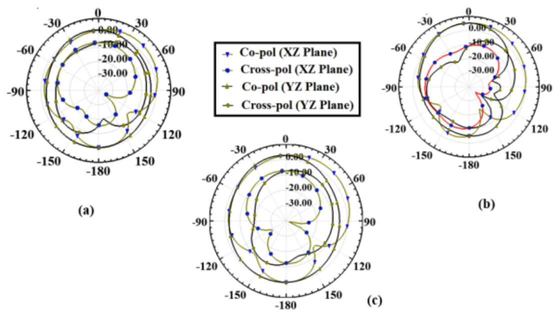

Fig. 5. Radiation patterns (a) 2.46 GHz (b) 3.3 GHz (c) 2.58 GHz.

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