A Compact Stair Case Monopole UWB Antenna for Radar Applications

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***Abstract*— A compact Ultra Wideband monopole antenna with improved gain and directivity is presented for microwave imaging applications. Introducing the staircase steps at the edges of the patch antenna improves the gain, bandwidth of the proposed antenna. Defective ground structures at the ground plane suppress the surface wave currents and result in a better impedance matching over the operating frequency of 1.6GHz – 10.2GHz for -10dB reflections. The proposed patch results in an improved gain and directivity of 5 dB and 6.35 dB respectively.**

***Keywords*— monopole antenna, defective ground structure, directivity, gain, UWB**

I. Introduction

Recently, in radar communication technologies the high data rate transmission is the major concern in various applications. Since the FCC has introduced the frequency range of 3.1 GHz to 10.6 GHz as UWB signal bandwidth a tremendous growth in commercial applications. In recent years, the research is mainly on the compact UWB planar antenna design for the various applications. Several types of UWB planar antennas are developed as per the required antenna parameters such as high directivity, high gain, wide bandwidth, and good impedance matching [1-4]. A directional ultra wideband antenna with planar technology is analyzed with various feeding techniques. The parabolic structured ground plane is used to obtain high directivity [5]. The combined effects of multiple slots and finite ground dimension result in a better impedance matching over UWB frequency range [6]. The UWB patch antenna must radiate at lowest and highest frequency with proper impedance matching. It is achieved by adding stepwise stairs at the edges and the upper surface of the patch radiator [7, 8]. By introducing notches at the proper dimensions and locations optimizes the ground plane effects on the patch radiator on the resonating frequency ranges .

II. Antenna Geometry

The proposed monopole antenna and its development is shown in Fig 1. The simple rectangular patch radiator results in a very narrow bandwidth with a reflection coefficient of -25dB. A multilayer structure of a human body has a capability to scatter the wideband signal at different frequencies according to the depth of penetration. For the medical imaging diagnostic applications, a highly directional and wide bandwidth UWB antenna is most preferable. The specified parameters are accomplished by incorporating staircase steps at the edges of the patch and defective ground structures. Optimizing the fringing fields between the edges of the patch and ground plane results in a better return loss.The following equations is used to calculate the dimensions.

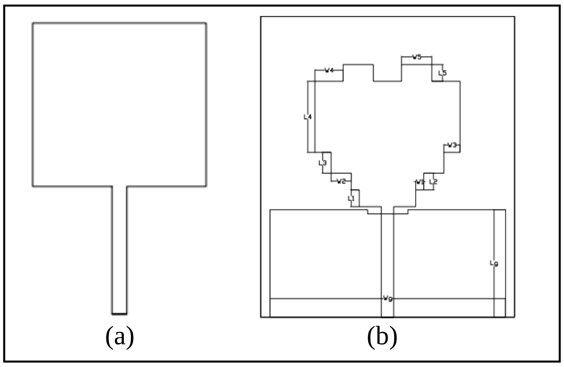

Fig. 1. a) simple rectangular patch b) Proposed UWB patch antenna

Given $\varepsilon_r = 4.4$, height = 1.6mm

$$W_p = \frac{v_0}{2 f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (2)$$

$$\frac{\Delta L}{h} = 0.412\left[\frac{\varepsilon_{reff} + 0.2\left(\frac{w}{h} + 0.264\right)}{\varepsilon_{reff} - 0.258\left(\frac{w}{h} - 0.8\right)}\right]^{-\frac{1}{2}} \quad (3)$$

$$L_p = \frac{v_0}{2 f_r \sqrt{\varepsilon_{eff}}} \quad (4)$$

TABLE I

DIMENSIONS OF THE PROPOSED ANTENNA

Parameters	***Values in mm***
Lp	34
Wp	36
Lsubstrate	72
Wsubstrate	63
L1	4
W1	2
L2	4
W2	5
L3	5
W3	4
L4	17
W4	7
L5	4
W5	7.5
Lg	25.7
Wg	58.5

III. Results and Discussion

The proposed patch antenna results obtain through simulation is presented. The antenna parameters such as return loss, gain, directivity, radiation patterns are discussed in this results. The proposed antenna structure has a broad bandwidth from 1.6 GHz to 10.2 GHz respectively. Since the antenna has the larger bandwidth, it is most suitable for microwave imaging applications. In microwave imaging applications the antenna has to receive maximize reflected signals to reconstruct the original image. The introduction of staircase modifications gives a better impedance matching at lower and higher frequency range. The proposed antenna results in an S11 of -40db at 1.9 GHz is shown in Fig. 2.

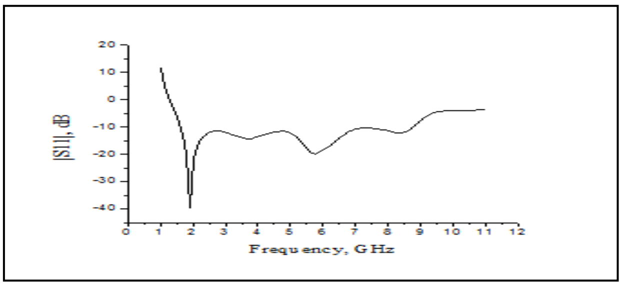

Fig. 2. Return Loss $|S_{11}|$, dB of the proposed patch antenna

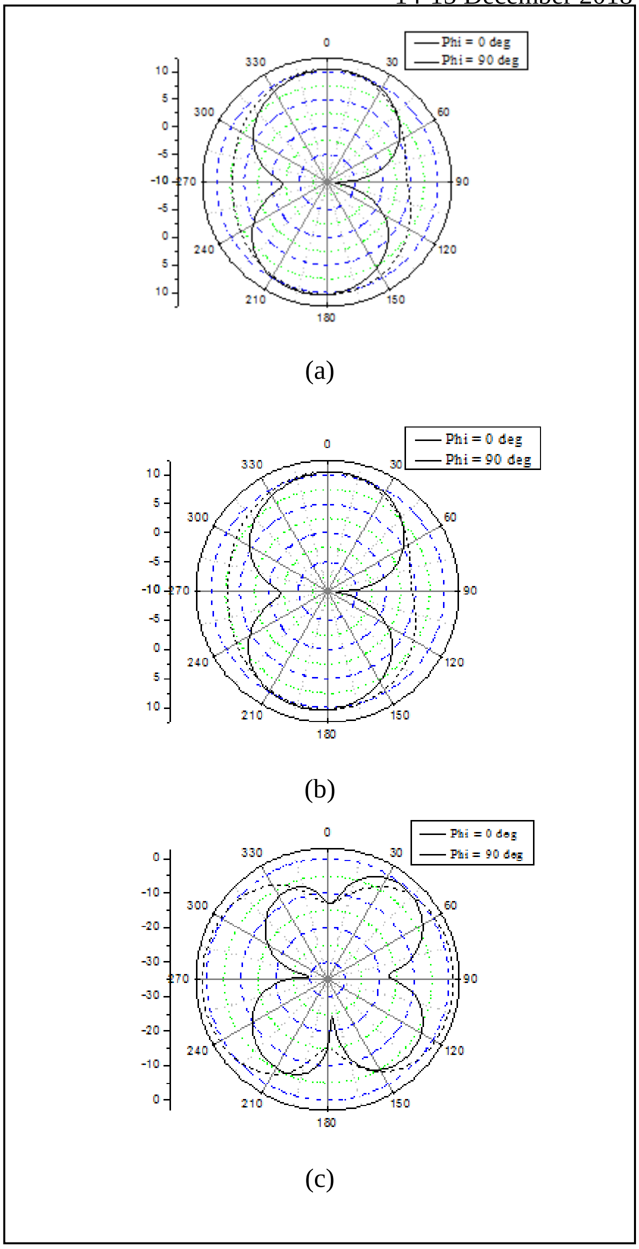

Fig. 3. Radiation pattern a) 2 GHz b)4GHz c) 6GHz respectively.

The radiation pattern obtained at various frequencies at 2 GHz, 4GHz and 6GHz are shown in Fig. 3. It is noticed from the figure that the antenna has the directional radiation pattern. Hence the proposed UWB antenna results in a highly directional radiation pattern. This high directionality in the planar antenna is the primary requirement for medical diagnostic imaging applications.

The 3D plot of the proposed antenna resultant gain is 5 dB at 7GHz is shown in Fig. 4 and the directivity is 6.35 dB is shown in Fig. 5. As the radiation pattern is directed towards the right side, it results in a unidirectional radiation pattern. In microwave imaging applications the antenna utilized as transceiver for radiating and receiving the scattered pulses. Hence the proposed antenna is best suitable for microwave imaging applications.

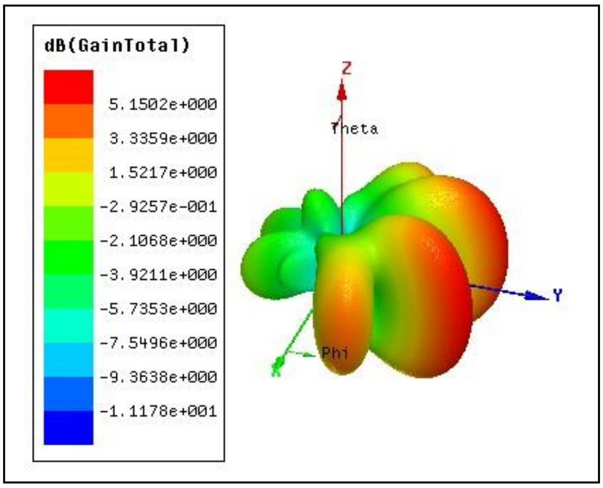

Fig. 4. Gain of the antenna

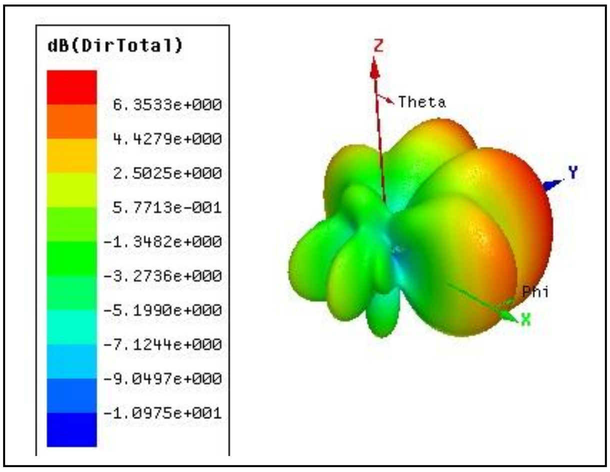

Fig.54. Directivity of the antenna

IV. Surface Current Distribution

In Fig 6 the current distribution of the proposed antenna is shown. It is understood that at low frequency the length of the antenna should be large and the current distribution is along the patch. As the frequency of operation increase, the dimension of the patch is decreased as per the general half the wavelength of the frequency of operation. From the figure, it is noticed that the current distribution is approaching the sharp edges at higher frequencies. In addition to this by introducing slots at both ends of the ground plane, the fringing fields between the upper radiating patch and the lower ground plane are better optimized to maximum field radiation. To improve the impedance bandwidth the slot at the bottom of the ground plane below the feed is used.

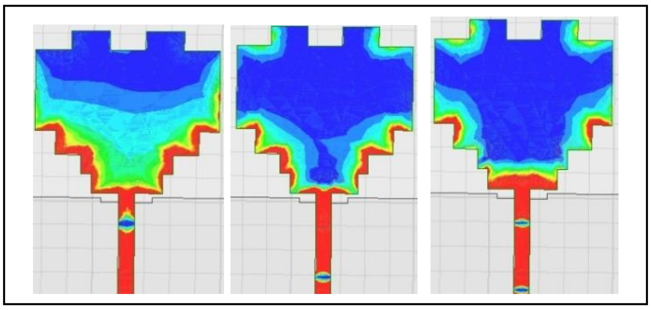

Figure 6. Current distribution of the proposed antenna at frequencies a) 2GHz b) 4GHz and c) 6GHz

V. Conclusion

A highly directive UWB patch antenna is designed and simulated using the HFSS electromagnetic simulation tool. The applied staircase steps and slots at the top of the patch results in a better impedance bandwidth from 1.6 GHz to 10.2 GHz respectively. The finite ground plane in addition to defective ground structure results in a wider bandwidth. The surface currents are also reduced by in the introduction of defective ground structures. The obtained results are the gain of 5dB, and the directivity is 6.35dB.

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