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Bandwidth Enhancement using Capacitive Coupling and Stubs in a Printed Wide Slot Antenna

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***Abstract*— A novel design of a dual band antenna, consisting of U-L shaped structure with wide slot in the ground plane is presented. To improve the bandwidth, capacitive coupling and stubs are introduced in the radiating element. Further to improve the bandwidth, a wide slot in the ground plane is employed. The proposed antenna is printed on 1.6 mm thick FR4 substrate which has a relative permittivity of 4.4 and a loss tangent of 0.008. The radiating element size is 20 X 18 mm^2. The measured impedance bandwidth for the first band is 3.7 - 4.2 GHz (12.66%) and second band is 5.3 - 6.9 GHz (26.23%) at 5.6 GHz. The peak gain is around 4 dBi at 5.6 GHz.**

I. INTRODUCTION

Due to rapid development in wireless communication, many dual-band antennas have been developed to meet the increasing demand for a modern wireless communication device which is capable of integrating more than one communication standard into a single system. In recent years, there has been much research done in the field of designing dual frequency antennas [1]-[6]. Further, many techniques have been proposed to increase the bandwidth. All the mentioned antennas in the literature have low bandwidth and larger in size.

In this paper, a novel design of a dual band antenna, consisting of U-L shaped structure with wide slot in the ground plane is presented. To improve the bandwidth, capacitive coupling and stubs are introduced in the radiating element. Further to improve the bandwidth, a wide slot in the ground plane is employed. This antenna not only has good dual-band operation performance, but also a simple structure and compact size.

II. ANTENNA DESIGN

The geometry of the proposed antenna front and back view is illustrated in Figures 1 and 2. The proposed antenna is printed on 1.6 mm thick FR4 substrate which has a relative permittivity of 4.4 and a loss tangent of 0.008. Figure 3 and 4 shows the front and back view of the fabricated antenna. The radiating element size is 20 X 18 mm^2. A 50Ω feed line having a width of 3 mm and length of 7.2 mm is used to feed the antenna centrally from the bottom edge of the rectangular strip. Here two ‘U’ shaped strips S_1 S_2 as shown in Figure 5, having lengths 23.9 mm and 23.6 mm respectively are operated at near frequencies, close to $\lambda_0/4$ length at 3.7 GHz and 3.9 GHz respectively. The length of S_1 and S_2 are These two Strips are connected by the 50 ohm feed line of length 7.2 mm and width 3mm. Above these two strips, one inverted ‘u’ shaped strip S_U structure is placed which connect the extended ‘L’ shaped strip S_3 and stepped ‘L’ shaped strip S_5. The total length of the inverted ‘u’ shaped structure is 18.9 mm, close to $\lambda_0/4$ length at 5.3 GHz. The distance between two vertical arms of the ‘U’ shaped structure is 6.4 mm.

The third and fourth strips (S_3 & S_4) are coupled by capacitive coupling effect. An open circuited stub of length 4.1 mm and width 0.4 mm is placed at the centre of the inverted ‘u’ shaped structure for fine tuning of the operating frequencies of the strips. In strips S_1 and S_5, there is a step like structure is introduced for impedance matching. Here the thickness of all the strips are not uniform hence impedance variations are there along all the strips. At the back side of the dielectric substrate, there is a wide slot of size 20 mm x 18 mm is placed impedance matching and to increase the bandwidth. Prototype of the proposed antenna have been constructed and tested. The antenna shape and its dimensions are first designed based on IE3D simulation software, and then the optimal dimensions are determined from experimental adjustment.

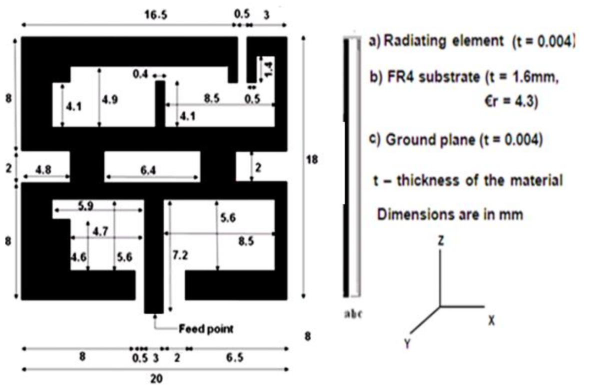

Figure 1.The Geometry of the U-L shaped antenna front and side view

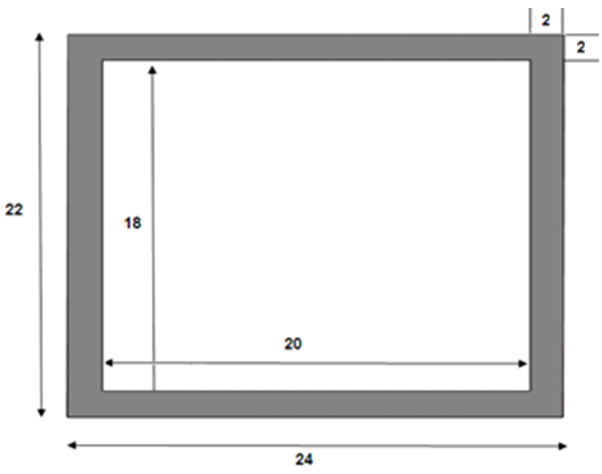

Figure 2. The Geometry of the U-L shaped antenna back view

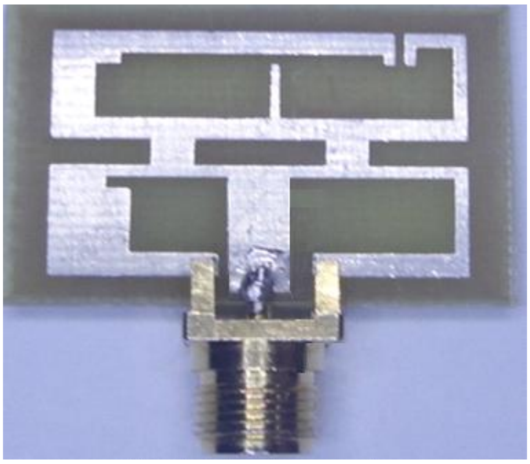

Figure 3 Fabricated U-L shaped antenna

Figure 4. Fabricated U-L shaped antenna with wide slot in the ground plane

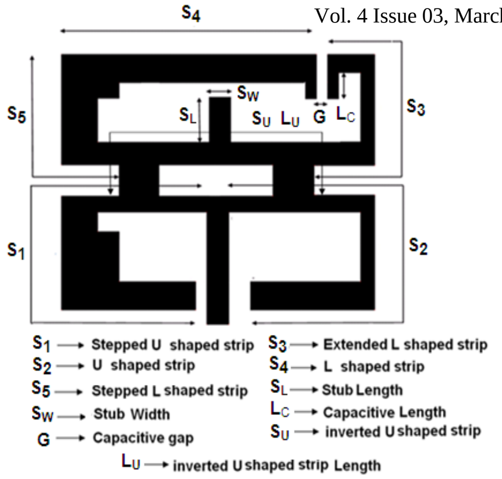

Figure 5. The parameters of the U-L shaped antenna

III. RETURN LOSS

Figure 6 shows the -10 dB return loss characteristics for the simulated and measured results. The measured impedance bandwidth for the first band is 3.7 - 4.2 GHz (12.66%) at 3.9 GHz and second band is 5.3 - 6.9 GHz (26.23%) at 5.6 GHz and 6 GHz. There is a good agreement between simulated and measured results. With the introduction of wide slot in the ground plane, the bandwidth is enhanced considerably. Figure 7 shows the return loss measurement using HP 8757D Scalar Network Analyzer for the U-L shaped antenna.

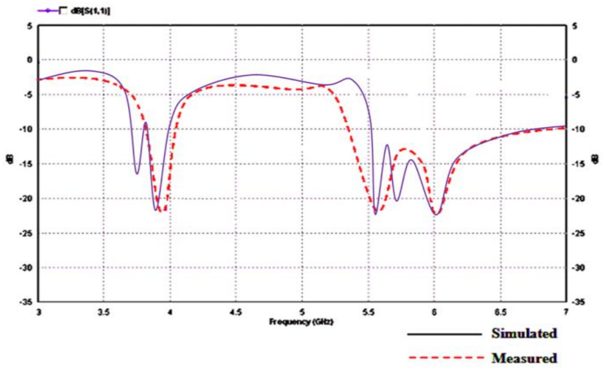

Figure 6. Return loss Characteristics of a U-L shaped antenna

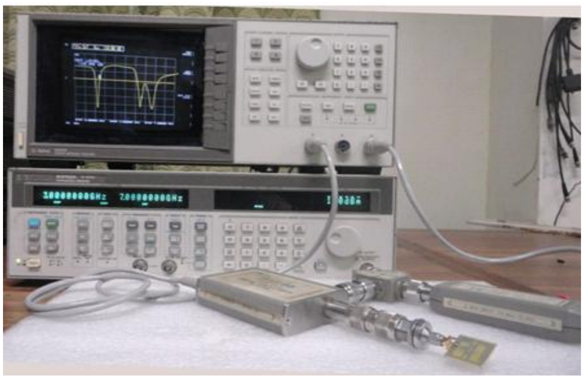

Figure 7. Return loss measurement using HP 8757D Scalar Network Analyzer for U-L shaped antenna

IV. CURRENT DISTRIBUTION

Figures 8(a) and 8(b), show the simulated surface current distribution of the antenna at two different frequencies 3.8 GHz and 5.6 GHz. At 3.8 GHz, the maximum current flow occurs in strip S_1 and S_2 and also in the inverted 'U' shaped strip S_U. By noticing the current distribution from Figure 8(a) it is concluded that each strip (S_1 & S_2) behave like a monopole and when they combined together, a dipole like characteristics is exhibited

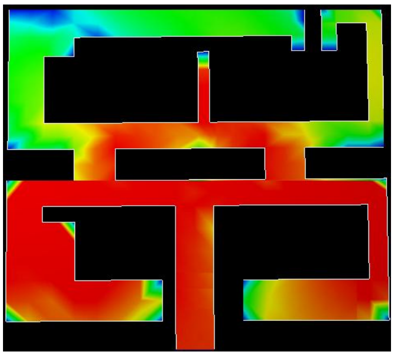

Figure 8(a). Surface Current Distribution at 3.8 GHz

At 5.6 GHz, most of the current flow occurs in strip S_3, S_4 and S_5. In all these strips, the current behaviour is just like a monopole because at one end the current is strong and other end the current is weak.

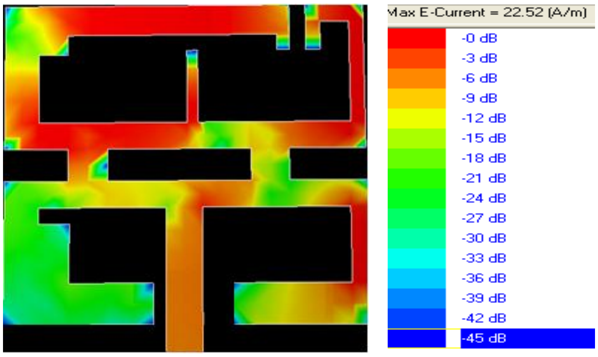

Figure 8(b) Surface Current Distribution at 5.6 GHz

V. RADIATION PATTERN

Figures 9 (a) and 9 (b) show the radiation patterns at 3.8 GHz and 5.6 GHz for the E-plane. At 3.8 GHz, the radiation pattern of an E-plane is like a small dipole leading to a figure of eight radiation pattern as shown in Figure 9(a) because the maximum current flow occur in strips S_1 and S_2 having a length of $\lambda/4$. At 5.6 GHz, the E-plane has monopole like radiation pattern. The H-plane as shown in Figure 9(b) has nearly omnidirectional pattern at 3.8 GHz and 5.6 GHz. The maximum current flow occur in strips S_1 and S_2 having a length of $\lambda/4$.

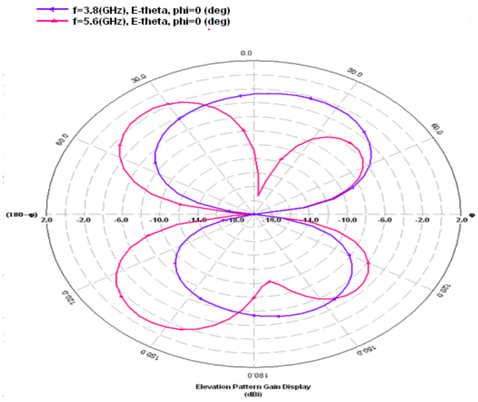

Figure 9 (a) Simulated Elevation pattern (E theta at 3.8 GHz& 5.6 GHz)

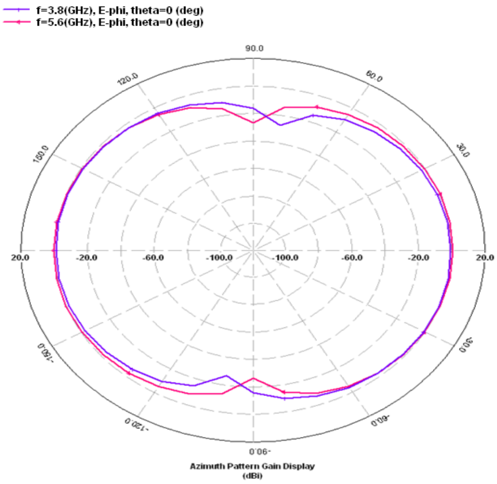

Figure 9 (b) Simulated Azimuth pattern (E phi at 3.8 GHz & 5.6 GHz)

VI. GAIN

Figure 10 shows the plot of Gain characteristics of a U-L shaped antenna. The peak gain is around 4 dBi at 5.6 GHz. The simulated peak gain at the lower operating band varies from 0 to 2.5 dBi, and at the higher operating band it varies from 0 to 4 dBi.

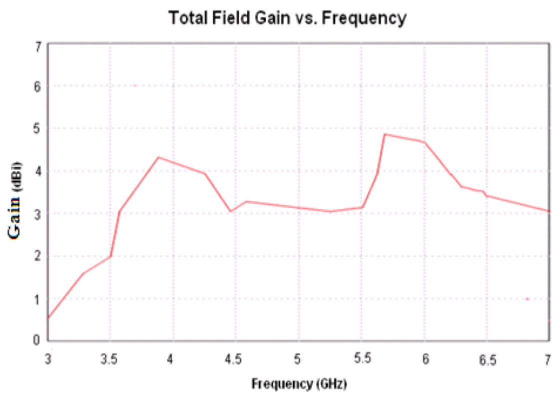

Figure 10 Gain Characteristic of a U-L shaped antenna

VII. CONCLUSION

A novel compact U-L shaped antenna with dual band characteristics has been presented and investigated. It is illustrated that by inserting a stub in the radiating element and wide slot in the ground plane with proper dimensions, the impedance bandwidth is enhanced. The radiation pattern of this antenna shows omnidirectional pattern in the H-plane. The measured -10 dB return loss bandwidth for the first band is 3.7 - 4.2 GHz (12.66%) at 3.8 GHz and for the second band is 5.3 - 6.9 GHz (26.23%) at 5.6 GHz. The peak gain is around 4 dBi at 5.6 GHz.

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