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Ultra-wideband L-strip proximity coupled slot loaded semicircular microstrip antenna

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Abstract: An analysis and design of a novel ultra wideband L-strip proximity coupled slot loaded semicircular microstrip antenna is proposed. The structure is simulated on MoM based IE3D simulation software and the results are verified with measurement. Simulated results show a good agreement with measured results. The patch is designed on a thick substrate of thickness 11mm for a center frequency of 8.93 GHz and provides ultra wide band operation. The parametric study is carried out for horizontal length of L-strip deviation of patch, and slot dimensions and return loss, radiation pattern, antenna efficiency, radiation efficiency and gain are obtained. It is observed that the bandwidth of the antenna depends on slot parameter and L-strip feed dimensions along with deviation of patch. An ultra bandwidth of 4.37 GHz is achieved with consistent radiation characteristics.

Keywords - Circular microstrip antenna, Bandwidth, L-strip, microstrip antenna, proximity coupled, slot, wideband, radiation pattern, antenna gain, radiation efficiency, return loss, directivity.

I. INTRODUCTION

Due to its inherent properties of light weight low cost, integratability, low profile etc. microstrip antenna has been used in transmission and reception of electromagnetic signals for wireless communication, aviation, mobile, and astronautics etc. However, it shows very small bandwidth that restricts the use of these antennas for wideband/broadband applications. Hence, many methods to enhance bandwidth have been developed [1-4] such as using gap coupled patched to the radiating and non-radiating edges [5-10], T-probe feed on thick substrate [11], impedance matching network [6], and. Antennas using thick substrate suffer from low efficiency due to dielectric loss and the reactance of longer probe restricts the bandwidth. An L-shaped microstrip feed has given considerable bandwidth in thick substrates with better coupling [13]. Recently the L-strip has become a popular feeding technique to design ultra wideband antenna [14, 15].

In this paper, an ultra-wideband proximity coupled L-strip fed semi-circular microstrip antenna (SCMSA) loaded with double slot has been proposed. Fig. 1 shows the proposed antenna, in which a foam layer of thickness 11mm is used as a substrate, an L shaped structure is used for feed and two rectangular slots are cut symmetrically in the antenna with narrow width to ensure capacitive coupling. The antenna is simulated with MOM based IE3D software. Further, parametric study of antenna for antenna efficiency, radiation efficiency, radiation pattern, gain and directivity is carried out. The details of entire investigations are present in the following sections.

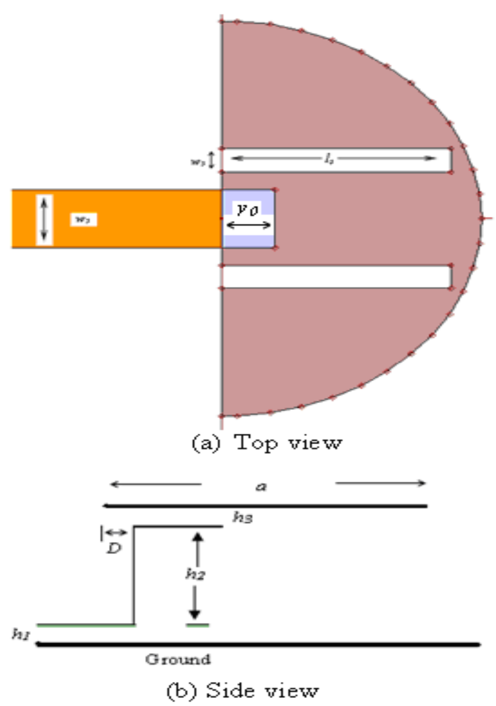

Fig. 1: Structure of proposed antenna

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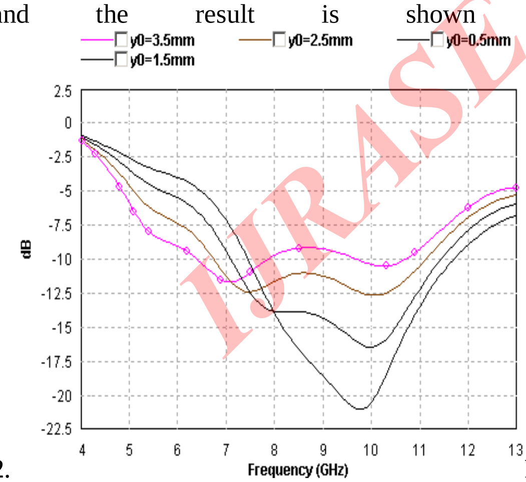
II. ANTENNA DESIGN

The proposed L-strip feed semicircular microstrip antenna, shown in fig. 1, is designed on thick substrate of foam material with dielectric constant very close to unity (1.07). Total height of the antenna is 11mm which is divided into three parts. The lower part with height of 1.6mm (h1) is used for microstrip feed design with characteristic impedance of 50 ohms. The width of the feed line (ws) is 5mm. The middle layer of the substrate consists of vertical part of L-strip feed with same width as of microstrip line on bottom layer. The thickness of middle layer (h2) is 7.8mm. At the top of this layer a horizontal line is made which is responsible for the power coupling to patch. The length of this line is 2.5mm. On the top of top layer with thickness of 1.6mm (h3) a semi-circular patch is designed with radius of 17mm (a) which has an offset of 0mm (D) from the feed line. Two slots are cut symmetrically along x-axis to bend the path of curvature of current lines. The length and width of both slots are 15mm and 1 mm respectively. The vertical part of L-strip provides inductance which is compensated by the capacitance created by horizontal apart of L-strip along with a resistance. These form a series combination of resistance, inductance and capacitance i.e. a series resonant circuit. This in turn comes in series with parallel resonant circuit of patch [14, 15].

III. RESULT AND DISCUSSION: The proposed antenna is simulated on MoM based full wave electromagnetic simulation software IE3D. The behavior of antenna on various antenna parameters is studied. The length of horizontal part of L-strip feed is varied while keeping all other parameters fixed and the result is shown in fig.



2. Fig. 2: Variation of Return loss with frequency for different y0

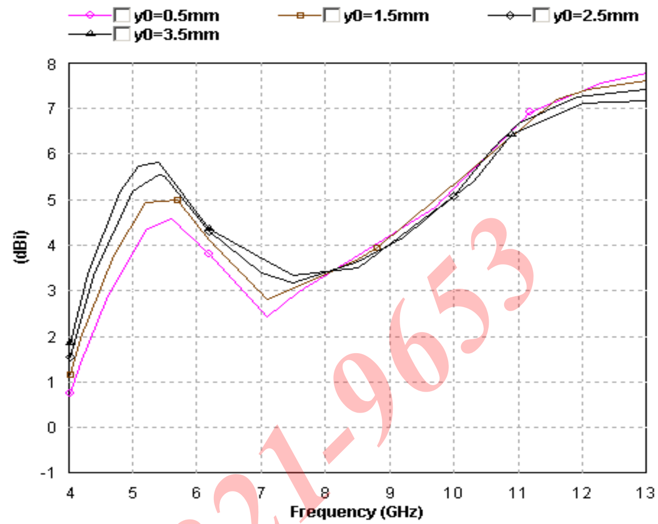


Fig. 3: Variation of gain with frequency at different y0

From the figure it is clear that the nature of antenna is dependent on y0. There are two resonances in the structure. As we increase the length of feed line the lower resonance is visible but the antenna becomes dualband from UWB antenna. Moreover, the upper resonance shifts upward with increase in length. The band of operation shift toward lower side of the spectrum. The bandwidth at y0=2.5mm is 4.37 GHz ranging from 6.75-11.12GHz. Fig. 3 shows the variation of gain of the antenna with frequency at different length of horizontal part of L-strip. It is clear from the figure that the gain of the antenna increases almost linearly with frequency for all lengths and that gain is similar for all.

Now, the length of slot is varied to understand the dependency of antenna return loss.

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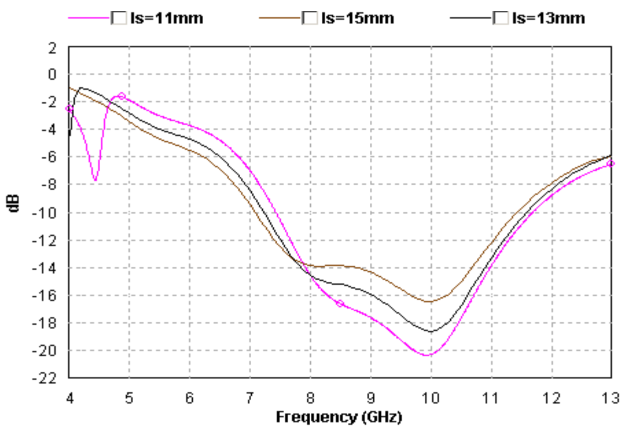

Fig. 4: Variation of return loss with frequency at different length of slots

The length of both the slot is varied simultaneously to see the behavior. The fig. 4 shows variation of return loss with frequency at different length of slot. As length is increased the matching deteriorates and band of operation shifts towards lower side of spectrum. The bandwidth remains almost unchanged while the lower resonance frequency decreases which is expected due to increased current path length. The upper resonance frequency remains unchanged.

Fig.6 shows variation of return loss with frequency for different width of slot. As width is increased matching improves but bandwidth decreases. The lower resonance frequency is decreased while upper remains unchanged at 10GHz.

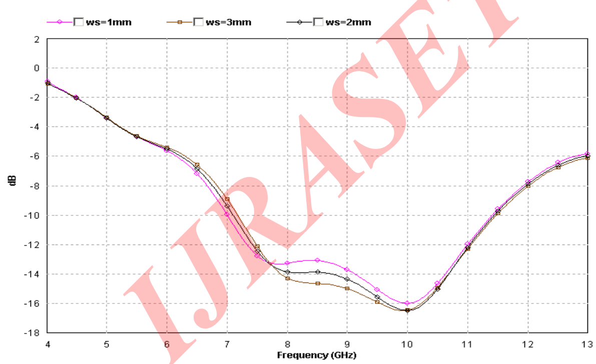

Fig. 6: variation of return loss with frequency at different width

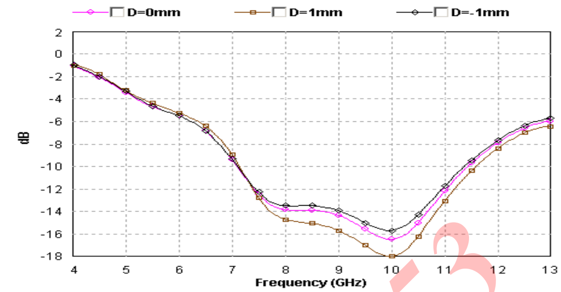

Fig. 7: Variation of return loss with frequency at different position of patch

The patch is shifted along x-axis and the behavior is studied. Fig. 7 shows variation of return loss with frequency at different offset of patch. The offset (D) is changed from

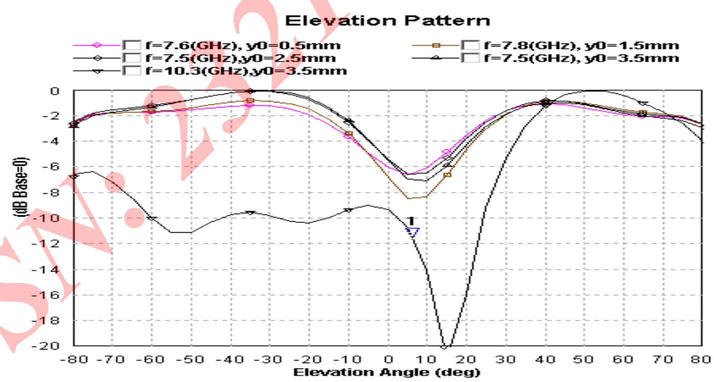

Fig. 8: Radiation pattern at different y0

-1mm (1mm towards left) to +1mm (1mm towards right) with 1mm gap. It may be observed that bandwidth and matching improves as the structure is moved towards right. As patch is moved from towards right the bandwidth increases as seen from table 1.

TABLE 1

BANDWIDTH VARIATION WITH OFFSET

D	Lower cut off	Higher cut off	Bandwidth
-1mm	7.1GHz	11.37GHz	4.27GHz
0mm	7.1GHz	11.43GHz	4.33GHz
+1mm	7.15GHz	11.6GHz	4.45GHz

The radiation pattern of the antenna at different length of horizontal part of L-strip is shown in fig. 8. The figure shows

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radiation pattern is plotted in the respective band of operation. It is clear form the figure that the antenna radiates at -300 for all values of y0 except 3.5mm which radiates at 510.

IV. CONCLUSIONS

A novel ultra wideband L-strip fed double slot loaded semicircular microstrip antenna has been presented. The proposed slot loaded antenna has operating bandwidth from 6.75 GHz to 11.12 GHz. More over the antenna provides flexibility to design a dualband antenna with slot dimension variation. The gain of the antenna is linearly increasing with frequency and unchanged with slot dimensions. Ultra-wideband characteristic is obtained due to the close proximity of resonant frequencies of L-strip ante patch. The radiation pattern is inclined and is useful for blind area coverage.

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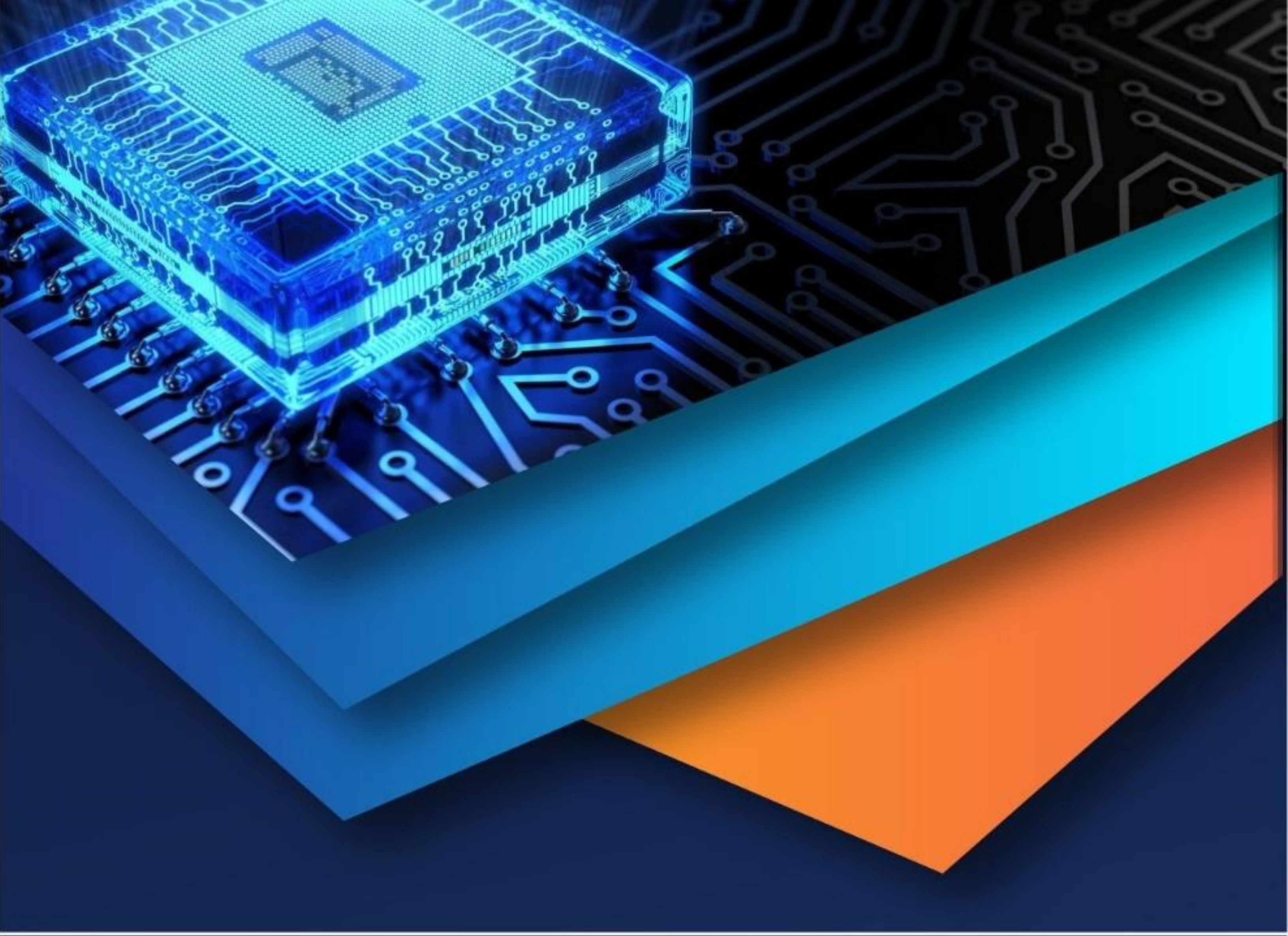

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