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Compact Broadband Rectangular Microstrip Patch Antenna

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Abstract— In this paper, using two or more U-slots which are mutually coupled, we are further able to extend the bandwidth achievable by single U-slot. Our Proposed design on 1.6 mm high FR4 substrate is 69 mm X 62 mm (L X W) in size which is vary compact, low profile and conformable. We have chosen licence free band from 7.6 GHz to 9.2 GHz which has not yet been targeted by any commercial product till now. We expect major wave of wireless product for Biomedical, Industrial, Defence and IOT applications in this frequency band in years to come. Our design achieves 1.6 GHz (20%) bandwidth around 8.3 GHz with fairly good gain achievable in low profile substrate. In our design we have introduce Microstrip ring to improve directivity of a antenna. The measured and simulated response shows close agreement thus validating our design.

Keywords- *Compact Antenna, Low Profile Antenna, Microstrip Antenna (MSA), Slotted Antennas, U-Slot, Broadband Antenna.*

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I. INTRODUCTION

Wireless communications has progressed rapidly in recent times especially during the last two decades. Current systems are designed for broadband multimedia application including high speed internet data, voice and video. These Ultra Wide Band (UWB) communication systems require broadband antennas. Another key feature of these systems is interoperability between different communications standards in different frequency bands. Such a requirement can be fulfill by multiband antennas. Thus major impetus in antenna design has been wide band and multiband performance.

Commercial applications require low cost radio. The major cost in radio is filters and antennas. Our work focuses on reducing the cost of antenna and widening the bandwidth for these modern broadband commercial applications. Microstrip patch antennas (MSA) on low cost substrate like FR4 are excellent choice for our design. Unfortunately the major drawback of these MSAs is narrow bandwidth. We proposed to overcome this demerit by utilizing slots in microstrip patches to widen their bandwidths.

In this paper, compact low profile Broadband rectangular patch antenna has been investigated thoroughly for exciting broadband with a gain nearly 6 dB. Although, the proposed geometry exhibits multiple S_{11} bands, but only one broadband resonance is useful as gain is positive at these frequencies. It will give 20 % bandwidth efficiency between 7.6 GHz to 9.2 GHz during simulation which is significantly used for indoor applications. We have taken various simulations during optimisation of geometry of proposed antenna which is discussed in following sections.

Section II presents basic geometry of the proposed antenna. Optimization of the final geometry and design implementation is presented in Section III. Experimental validation of the work is presented in Section IV. The conclusion and possible extension of the work is presented in Section V.

II. PROPOSED DESIGN

The conventional rectangular MSA is shown in Figure 1 whereas modified rectangular patch, modified ground plane and proposed microstrip patch antenna with coaxial line feeding are shown in Fig. 2, and its optimized dimensions are listed in Table 1.

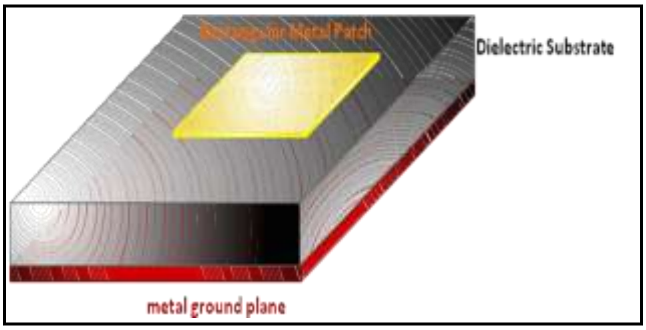

Figure 1: Conventional Rectangular (MSA)

The proposed antenna is designed using FR4 substrate with relative permittivity (ε_r) 4.4, thickness (h) 1.6 mm and loss tangent 0.0016. The diameter of the feeding hole is 1.4 mm.

In this proposed design, on a rectangular patch, two U-Slots are added to excite broad resonance band and also to enhance the gain and bandwidth of resonance band. The proposed geometry was designed and optimized on the substrate of glass epoxy (FR4) with thickness of 1.6 mm, dielectric constant of 4.4, and a loss tangent equal to 0.01. The antenna is simulated using Ansoft's High Frequency Structure Simulator (HFSS) 13v which is electromagnetic (EM) simulation software.

III. Design Optimization and Implementation

The detailed optimization procedure of the proposed antenna and its optimum dimensions, and characteristics are presented in this section.

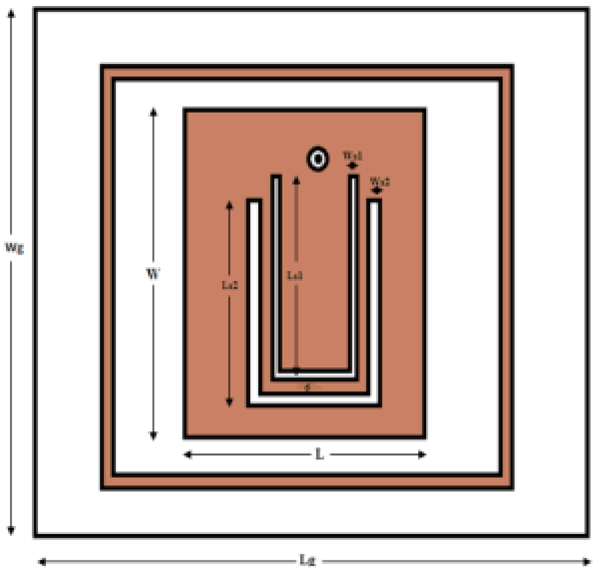

Figure 2: Proposed Microstrip Antenna

In this section parametric study is conducted to optimize the proposed antenna geometry. The key design parameters used for the optimization are length of the outer & inner U-slot arms, width of the outer & inner U-slot arms, and gap (d) between outer & inner slots. The detailed analysis & effect of these parameters on the geometry performance is investigated in the following subsections. All simulations were carried out with the help of HFSS 13v software.

A. Effect of L_{s1}

The length of inner U-arms is varied by 1 mm from 20 mm to 24 keeping all other parameters of geometry constant. The effect of length variation on reflection coefficient (S_{11}) and gain characteristics of antenna are observed in simulated graphs. From the study of graphs in simulation it can be noticed that the maximum gain of more than 6 db was obtained at length of 22 mm.

B. Effect of L_{s2}

In this case, the length of outer U-arm was varied from 18 mm to 22 mm in steps of 1 mm with all other parameters kept constant. The results are observed and it may be noted that the optimum results can be obtained for length of 20 mm.

C. Effect of W_{s1}

The width of outer U-slot arm is varied from 0.25 mm to 1.75 mm in steps of 0.25 mm keeping all the parameters constant. From these variations it is observed that the increase in the width of inner slot results in the drop of performance of antenna. It can be noticed that the geometry exhibits optimum performance for width of 1 mm.

D. Effect of W_{s2}

The effect of outer U-slot width on geometry performance was observed carefully. The width of these two arms is changed from 1 mm to 2.5 mm in steps of 0.25 mm keeping all the parameters constant. From following figures it is important to note that the optimum results with higher gain & better reflection coefficient characteristics are obtained at the width of 2 mm.

E. Effect of d

The spacing between the U-slots was investigated. The spacing between these slots is varied from 0.2 mm to 0.8 mm in steps of 0.1 mm keeping all the parameters constant. The optimum results were obtained for the gap of 0.5 mm. From this study it can be noted that the resonances shift towards right as the gap between slots increases. The maximum gain obtained for the optimum case is 6 dB when the spacing between two slots is 0.5 mm.

Table 1: Dimensions after Optimization

Parameter	L_g	W_g	L	W	L_{s1}	Ws_1	L_{S2}	W_{S2}	D
Values (mm)	69	62	24.9	36.5	22	1	20	2	0.5

IV. Experimental Validation Of The Geometry

The geometry of compact low profile rectangular patch microstrip antenna shown in Figure 2 with its optimized dimensions presented in Table 1 which was fabricated and tested. A thin substrate which is available easily is used for the fabrication of antenna. It is the FR4 glass epoxy material with the thickness of 1.6 mm, dielectric constant (ε_r) of 4.4, and the loss tangent 0.01. The figure of fabricated prototype antenna is shown in Figure 3. Reflection coefficient characteristics (S_{11}) of measured and simulated values are compared in Figure 4.

Figure 3: Fabricated Prototype of Optimized Geometry

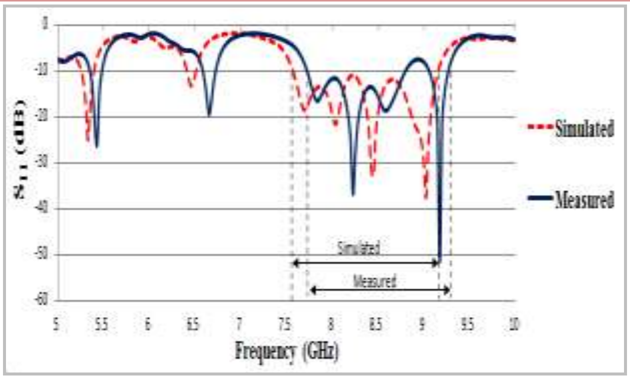

Figure 4: Return loss (S_{11}) characteristic plot of the proposed antenna

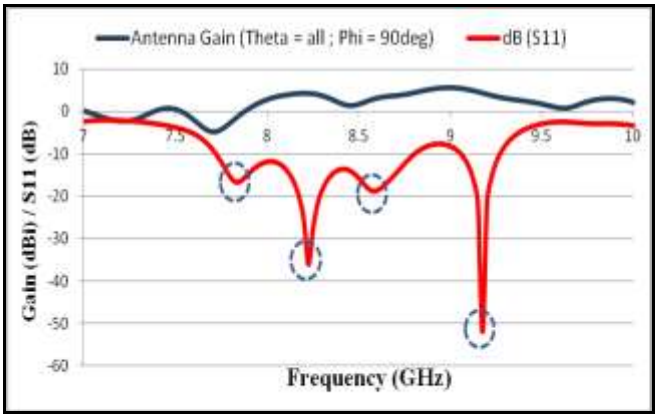

Figure 5: Antenna gain and return loss across frequency.

Figure 5 shows gain and return loss of the antenna in designed frequency range, 7.5 GHz to 9.2 GHz. Figure 6 shows far field radiation pattern of the antenna across the frequency band. The measured results fairly agree with the simulated values.

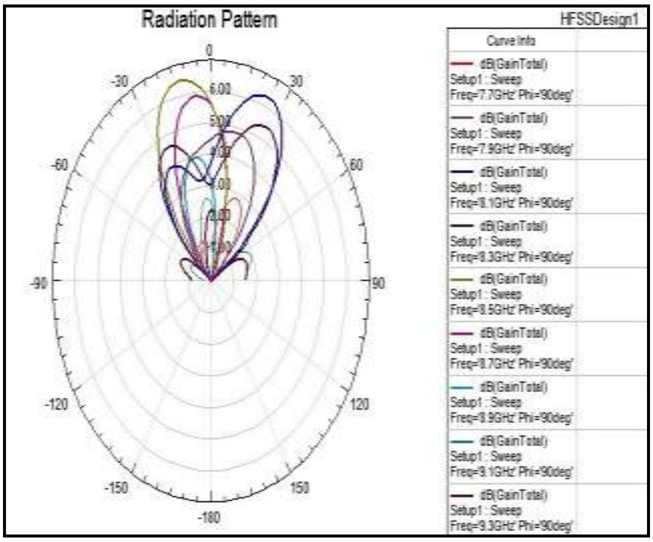

Figure 6: Far field radiation pattern of the antenna across the frequency band.

V. Conclusion and Future Work

The simulated and measured response of the antenna is in close agreement. The return loss shows four distinct resonant frequencies corresponding to following

- The lowest resonant frequency corresponds to the resonant length of patch
- The highest resonant frequency corresponds to length of inner U-slot
- The second highest resonant frequency corresponds to mutual coupling between the outer U-slot and Inner U-slot
- The third highest resonant frequency corresponds to length of outer U-slot

The current research can be extended to investigation of coupled U-Slots in triangular and circular patches. We have used coaxial feed in our design which limits antenna bandwidth to 20 – 25 %. A proximity feed or a matched microstrip feed is expected to further enhance the bandwidth to 40 %. Multimode excitation of our design patch can also be used to shape the beam as well as to steer the beam.

Other drawback in our design is low power capability which can be overcome through air suspended u slot patch. Shorting stub can also be used to further make the antenna compact for handheld applications.

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