Analysis of Stacked Patch Antenna with Variation in Couplers in Ultra Wide Band

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***Abstract* - A compact stack antenna consisting of square patch, loop couplers and inset feed line with a slot is proposed in this paper. The proposed design have a stacked patch antenna with an arrangement of two substrates separated by an air gape, A coupling is provided using square loop structure. A variation in coupler structure is done to make the antenna work at multiple frequencies in UWB range. The simulation result of this work with different resonator structure is presented and comparative analysis of these different arrangements is presented in this paper. Simulation is done using CST Microwave and the result obtained are suitable for ultra wide band application.**

Keywords - *Microstrip antenna, Return loss, Bandwidth, VSWR, Reflection Coefficient*.

I. INTRODUCTION

In today's wireless world and communication era the broad-and multi-band nature antenna are dominating. Need is of advancements which are compatible to requirement, techniques for enhancing bandwidth and size reduction mechanism that improves the performance of a conventional microstrip patch antenna. As there is an increasing demand for newer microwave and millimetre-wave systems to meet the emerging telecommunication challenges with respect to performance. size and cost. Microstrip antennas offer the advantages of thin profile, low cost, light weight, ease of fabrication and compatibility with integrated circuitry but still a major disadvantage is their inherent narrow bandwidth [1]. It is important to design broadband antennas to cover a wide bandwidth to meet the ever-increasing demands for mobile communication. The proposed design also cover new emerging systems like Ultra-wideband (UWB) communications systems for the use of the frequency between 3.1 to 10.6 GHz which have been investigated and developed over the last few years. The prosed design has the high-speed transmission rate in short-range with lower power consumption, simpler hardware configuration in communication applications.

An antenna consisting of square loop resonators, aperture couples and feed line [1,2] is designed for a dual band operation where the stacked structure is utilized for multiband structure. A stacked structure applied to an equilateral triangular microstrip patch antennas shows reduction in its overall size [3], the stacked structure is also utilized for bandwidth enhancement [4-6].

This paper consist four sections as follows: Brief Introduction and related work are presented in Section I. Section II explains basic design geometry of the antenna. Simulation results and their comparative analysis with different couplers and comparative study of VSWR is presented in Section III . Conclusion and future aspects of the proposed work is presented in Section IV.

II. ANTENNA DESIGN

The proposed antenna has a simple square patch using an inset feed; the patch antenna is designed using the basic concepts of the microstrip technology.

A. Basic theory

In general microstrip patch antenna consist of a patch of metal that is on the top of a grounded dielectric substrate.

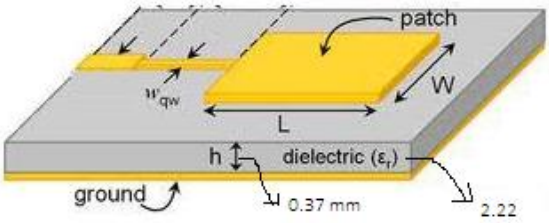


Fig. 1 Geometry of rectangular microstrip patch antenna

The metallic patch may be of various shapes, patch of rectangular and circular shape being the most common; the geometry of a Rectangular Microstrip Patch Antenna (RMPA) is shown in Fig. 1. The patch of length 'L', width 'W' and thickness 't' is printed on RT- Duroid (ε_r = 2.22) substrate of thickness h.

B. Proposed Design

The proposed antenna shown in Fig. 2 is composed of a Perfect Electric Conductor (PEC) ground plane, substrate 1 which is RT-Duroid (ε_r = 2.22, h = 0.37 mm) above which a square loop structure is printed with PEC, an air gape is introduced between the first loop and second loop which is printed on the bottom of the substrate 2 RT-Duroid above this substrate the PEC patch is printed with inset feed line.

Fig. 2 Cross sectional view of the stacked structure patch antenna

The dimensions of the patch are evaluated using the standard design equations which are mentioned in Appendix. Through calculation the patch optimized to a value of 14 x 14 mm^2 , both the substrates have dimension 25.4 x 25.4 mm^2, length of the inset feed line is optimized to 10.2 mm with a calculated width of 1.2 mm. The coupling loops 1 and 2 are squares of sides 18 mm and 15 mm respectively, the ground plane used here is defective ground structure (DGS) with dimensions 25.4 x 13 mm^2 . The DGS helps in shifting the resonant frequency to get desired frequency [9], by combining with a DG plane, the bandwidth is augmented and the resonant frequency is lowered simultaneously [10]. DGS helps in convergence of field in a relatively small region shifting the high frequencies at lower dimensions, ultimately playing a significant role in size reduction.

III. Simulation Results and Analysis

Simulations results carried out for the proposed design (Fig. 3) with the optimized dimensions is as follows:

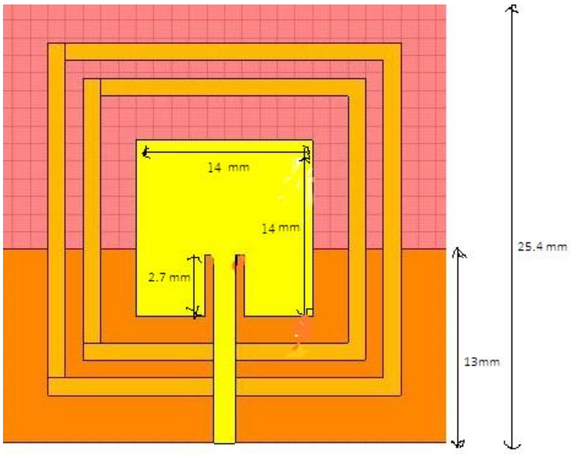


Fig. 3 Top view of the stacked structure patch antenna

The Return loss (S_{11} in dB) obtained is less than 10 db on two frequencies as can be seen from Fig. 4 . Initial results shows that one antenna has dual frequency operation .

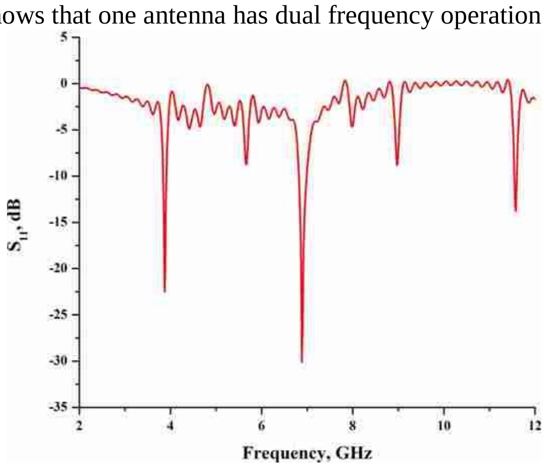


Fig. 4 S_{11} parameter of the proposed design

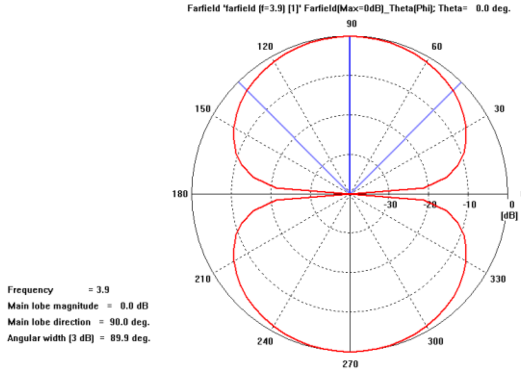


Fig. 5 Far Field E- Field of proposed antenna at 3.9GHz

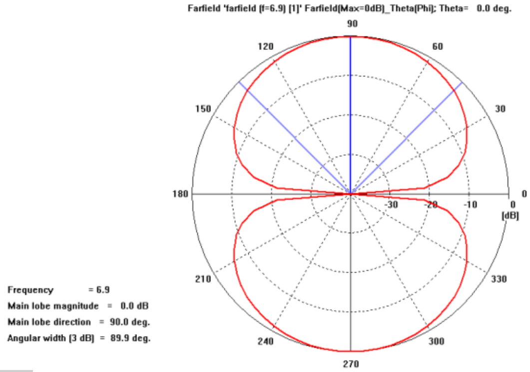
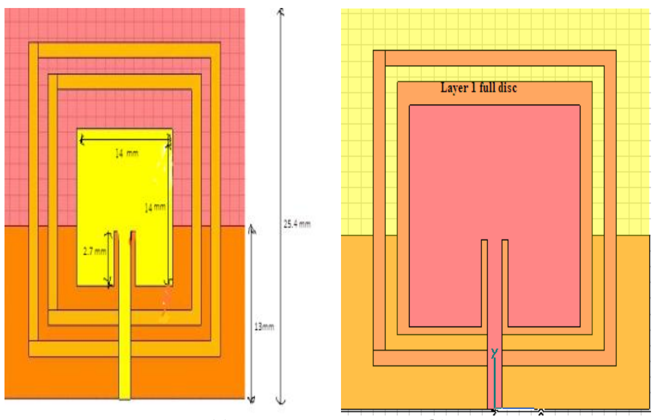


Fig. 6 Far Field E- Field of proposed antenna at 6.9 GHz

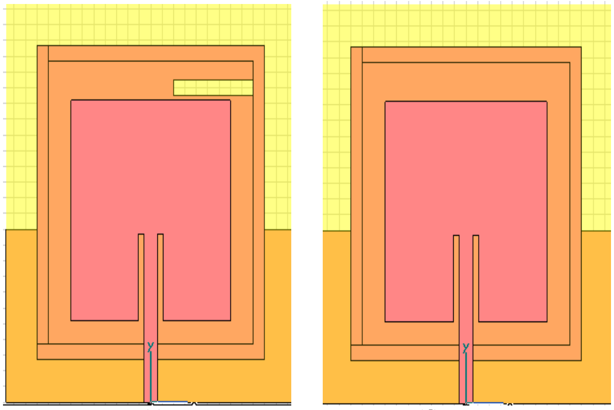
The respective radiation patterns for the central frequencies of the two bands i.e. at 3.9GHz and 6.9 GHz are shown in Fig. 5 and Fig. 6 and it can be observe from the radiation patterns that the far-field pattern is invariant of the frequency.

C. Analysis of antenna with different resonating structures

To extend the possibilities of bandwidth improvement in the proposed design some variations in the resonating structure is done, however other dimensions of the patch where kept same. The arrangements of the stacked structure with loop resonator Fig. 7(a), small disc resonator Fig. 7(b), disc resonator with a slit Fig. 7(c) and large disc resonator Fig. 7(d) are simulated in the same frequency range and return loss observed shown in fig. 8 are -21 db,-35 db, -27 db and -28 db respectively.



(a) (b)



(c) (d)

Fig. 7 Top view of the antennas with (a) loop resonator (b) small disc resonator (c) disc resonator with a slot (d) large disc resonator

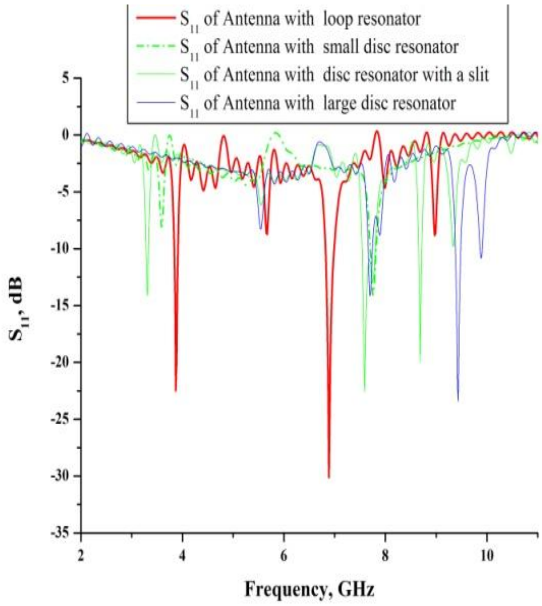


Fig. 8 S_{11} parameter of the proposed designs with different feed arrangements

As it can be observed from Fig. 8 that the return loss (S_{11} parameter) and the bandwidth of the proposed antenna is changing significantly with each variation in resonating structure. As per the simulated output obtained for design with loop resonator antenna Fig 7(a) operates on dual frequencies at 3.9GHz and at 6.9 GHz respectively and bandwidth obtained 3 GHz. When the lower loop of the resonator is replaced by disc Fig.7(b), the result obtained from antenna operation on frequency 7.75 GHz and bandwidth is 1 GHz. The design with disc resonator with a slit Fig 7(c) operated on triple frequency operation at 3.3 GHz, 7.59 and 8.68 GHz respectively and bandwidth is 3.7 GHz. The design with large disc resonator Fig 7(d), frequencies of operation obtained are 7.69 GHz, 9.43 GHz and 9.88 GHz respectively, The bandwidth is 1.2 GHz . These result shows that the proposed antenna is suitable for communication in UWB.

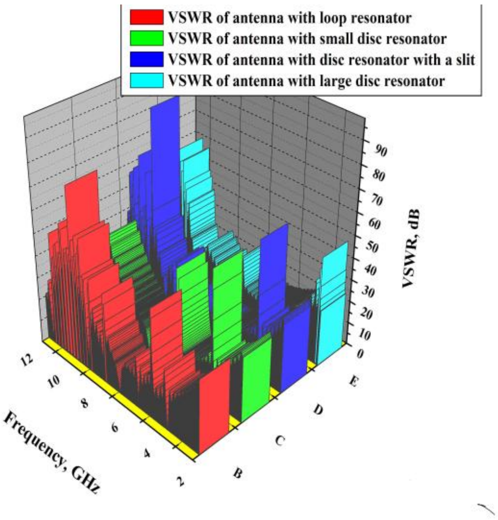


Fig 8. Comparison of VSWR of designs 7.(a),(b),(c) and (d)

In Fig. 8 comparison of VSWR is presented .It can be observed that VSWR is maximum 40 db at 6 Ghz in UWB fordesign 7(a).The 45 db gain is achieved for design 7(b) at 7 Ghz. The design 7(c) gives 50 db gain at 4.5 Ghz. The design 7(d) gives 30 db gain at 7 Ghz. So the maximum gain is also obtained by the slot induced in the design.

IV. CONCLUSIONS

The proposed design of antenna shows the enhancement of bandwidth with improvement in gain. The antenna is useful for Ultra Wide band applications.

APPENDIX

The following equation were used for design of antenna geometry[3,7]

For Calculation of width($w1$) :

$$w1 = \left(\frac{v0}{2fr}\right)\sqrt{\frac{2}{\epsilon r+1}} \qquad (1)$$

Where,
'v_0' is the velocity of EM wave;
'w_1' is the width of patch;
'ϵ_r' is the relative permittivity of substrate;

For calculation of effective dielectric constant(ϵd_{reff}):

$$\epsilon\, dreff = \frac{\epsilon r+1}{2} + \left(\frac{\epsilon r-1}{2}\right)\left(1+12\left(\frac{h}{w1}\right)\right)^{-\frac{1}{2}} \qquad (2)$$

Where,
'ϵ_{dreff}' is the effective relative permittivity of patch;
'ϵ_r' is the relative permittivity of substrate;
'w_1' is the width of patch;
'h' is the height of substrate;

For calculation of Effective length ($l1_{eff}$):

$$l1eff = \frac{v0}{2f0\sqrt{\epsilon eff}} \quad (3)$$

Where,
'l_{1eff}' is the effective length of patch;
'v_0' is the velocity of EM wave;
'f_0' is the resonant frequency;

For calculation of Length extension(Δl):

$$\frac{\Delta l}{h} = \frac{0412(\epsilon dreff+.3)\left(\frac{w1}{h}+.264\right)}{(\epsilon dreff-.258)\left(\frac{w1}{h}+.8\right)} \quad (4)$$

Where,
'ϵ_{dreff}' is the effective relative permittivity of patch;
'w_1' is the width of patch;
'h' is the height of substrate;
For calculation of actual length of patch(l):

$$l = l1eff - 2\Delta l \quad (5)$$

Where,
'l_l' is the length of patch;
'Δl' is length of extension;

For calculation of ground plane dimension(l_g and w_g):

$$lg = 6h + 1 \quad (6a)$$

$$wg = 6h + 1 \quad (6b)$$

where,
'h' is the height of substrate;
'l_g 'and 'w_g ' are length and width of ground plane respectively.

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