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Research paper



A Small Square Monopole Ultra-wideband Antenna with Band Stop Behavior

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Abstract

A monopole antenna with a simple structure, planar geometry, and a small square size is proposed, in this paper. The proposed antenna structure consists of the slot with I-shaped geometry in the radiating patch surrounded by a C-geometry slot. Further, the structure contains a parasitic I-shaped element in the square radiating patch. The embedded slot with C-shaped geometry and parasitic I-shaped element accounts for the dual-band notch nature in the proposed antenna structure. The simulated and measured results are compared for the proposed antenna structure, which is in good agreement and also, band rejection capabilities of the proposed antenna are investigated.

Keywords: *Monopole; notch; slot; UWB.*

1. Introduction

Ultra-wideband (UWB) antennas innovation has pulled in more consideration both in the business and scholastics because of its ease, capacity to handle high information rate and very low power requisite. They are the most widely used antennas because of their low cost, broad bandwidth, compactness, Omni-directional radiation pattern, constant group delay over whole operating frequency, low standing wave ratio and high data rate [1]. The UWB technology with a frequency range of 3.1–10.6 GHz get more importance after it got license free status from FCC in 2002 [2]. The main requirement of present scenario is to design compact antennas with wideband characteristics, to avoid the multipath issue and to avoid interference from other existing bands. To avoid interference from the coexisting narrowband systems like IEEE 802.16 WiMAX band, IEEE 802.11a WLAN bands, C band, and ITU 8 GHz band, it is important to create notch band or stop band. We have seen various methods till yet to create stop band using slots of various shapes in the radiating element and ground plane [3–7].

The band stop behavior may be altered by controlling the width, length, and number of slots. The electrical length of the slot has a significant blow over the rejected band bandwidth. Techniques like square ring resonator and two parasitic patches are used to design notched band antennas are comparatively complicated [8, 9]. If the combination of open stub filter & Spur-line filter is used, it shows deeper rejection without increasing the circuit size and wider stopband than any conventional open stub filter [10]. By inserting a square ring resonator in a tuning stub [11], stable radiation pattern can be obtained. On the bottom side of the substrate, the use of parasitic patches about the radiation patch [12] or by the collection of a pair of L-shaped branches on to the radiating patch [13] creates band stop property.

Band stop filters in series with an antenna are used to create notched band but also it will cause design complexity and increase the weight of the antenna [14]. Substrate integrated waveguide cavity filter can also cause notch band, if it would be integrated within the feedline [15] but it will degrade antenna performance. Many of the UWB antennas are reported which uses resonant slot into the inner part of the mono-planar antenna [16-20]. Most of them exhibit poor return loss greater than 1dB [17, 21] and complex design [21-23]. Adding parasitic strips or resonators near the radiator or feedline but with the use of one resonator, we can't meet the requirement of sharp selectivity. Other methods to create stop band are using Electromagnetic Band Gap structures, integrated stop-band filters and frequency selective surfaces above the antennas. The use of resonators such as CPW resonator, CLL resonator, a square ring resonator, open loop resonator, etc. on the other face of the substrate also produces band stop behavior [24–26]. In literature, quadruple frequency bands can be rejected by using resonant spiral structures that are capacitively coupled structures with feed line [27]. The use of stub within T-shaped slot also produces notch band characteristics [28]. While creating notch bands, the problem of mutual coupling is also needed to be considered. The stub can minimize the problem of mutual coupling; the mid-frequency of stop band may be altered or adjusted by varying the length, width, and position of the stub. Photonic band gap structure increases the radiation antenna facing away [29]. By configuring p-i-n diodes, stop band behavior of the antenna can be obtained. However, these methods of creating band notch are complex and require a lot of optimization.

In this paper, a novel planar monopole UWB antenna with compactness and simple geometry is presented. The slot with I-shaped geometry loaded in the antenna excites some additional resonance leading an improvement in impedance bandwidth. For creating a notch band, the presented antenna has slot with I-shaped geometry which is further surrounded by a C-shaped slot which is in the patch.

More, the dual notch band is created using a parasitic element inside the slot of the radiating element. The presented structure has smaller size compared to the existing antenna designs with dual-band notch performance. The antenna consists of impedance

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bandwidth which is wide, the gain is moderate & radiation pattern is omnidirectional.

2. Antenna Design Methodology

The antenna design consists of an FR4 substrate of dimension 12 x18 mm^2 with thickness 1.6 mm and relative permittivity of 4.4. The geometry of proposed antenna is shown in Fig. 1. The basic structure configuration contains a square radiating element, finite rectangular ground plane and a microstrip feedline of 50Ω to excite the structure. A 50 Ω SMA connector can be used for providing the input transmission. The I-shaped slot along with C-shaped slot perturbs the resonating behavior of the patch resulting in a single notch band. Further, based on the concept of electromagnetic coupling, a parasitic element of I-shaped geometry is put inside the slot of I-shaped geometry. The embedded parasitic element is responsible for the second notch band response. The designing schematics of the presented structure is expressed in Fig. 2. By inserting a slot of I-shaped geometry in the conventional square patch (Fig. 2(a)), additional resonance is excited, thus an improvement in -10 dB impedance bandwidth is achieved. The antenna's optimized dimensions are given in Table 1. This antenna structure is designed using commercially available simulator Ansys HFSS.

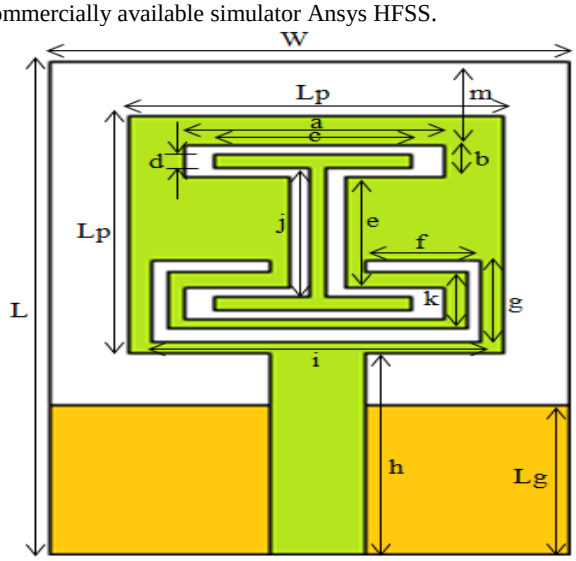


Fig. 1: Proposed antenna Geometry

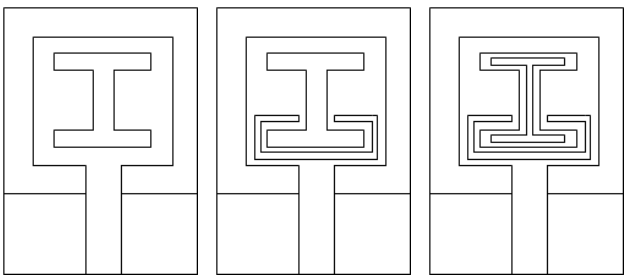


Fig. 2: Designing schematic of the proposed antenna (a) Simple square with the slot of I-shaped geometry (b) Simple square with I-shaped and C-shaped slot (c) Proposed antenna

Table 1: Dimensions

Dimension	mm	Dimension	mm
L	18	*e*	5
W	12	*f*	2.65
Lp	8	*g*	1.85
Lg	8	*h*	8.5
a	7	*i*	7.8
j	5.5	*b*	1
k	1.35	*c*	6
d	0.5	*m*	2

3. Results and Discussions

Initially, Simple Square with the slot of I-shaped geometry has been designed. Fig. 3 represents simulated the return loss characteristics of the simple square I-shaped slot loaded antenna, a square patch antenna with I-shaped and C-shaped slot loaded and proposed antenna. The proposed antenna has square patch loaded with I-shaped and a C-shaped slot along with I-shaped parasitic element placed inside the I-shaped slot. It can be seen that by loading I-shaped slot in the square patch, a change in impedance bandwidth of designed antenna has been seen. For this reason, the embedded I-slot excites additional resonance, thus effectively improving the lower frequency range. In the given fig. 3, it is observing that for obtaining stop band behavior, a slot of C-shaped is loaded across the slot of I-shaped geometry. The other stop band gets by placing a parasitic element of I-shaped inside the I-shaped slot.

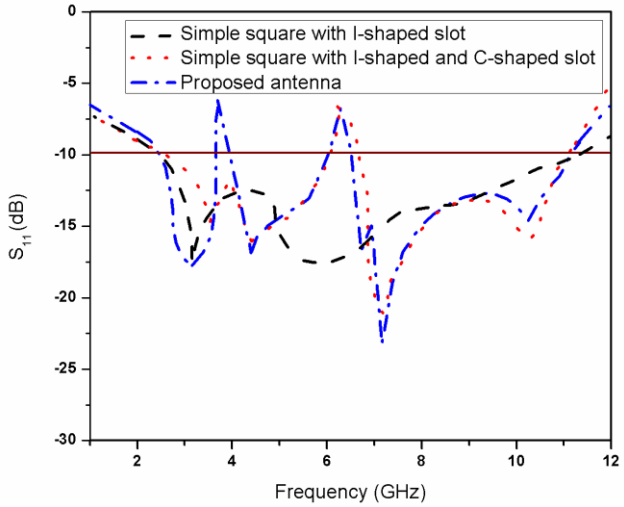


Fig. 3: S_{11} comparison of Fig. 2.



Fig. 3: Fabricated antenna of proposed configuration

For the verification of proposed antenna configuration, the prototype antenna has been fabricated on the low-cost FR4 substrate having a relative permittivity of ε_r= 4.4, a dielectric thickness of *h*= 1.6 mm and the loss tangent *tanδ*= 0.02. The photograph of fabricated antenna is shown in Fig. 4, SMA connector of center conductor of radius equal to 0.6 mm was used and soldered at the end of microstrip line feed. The simulated and measured results have been compared in Fig. 5, for return loss, and which are in good agreement.

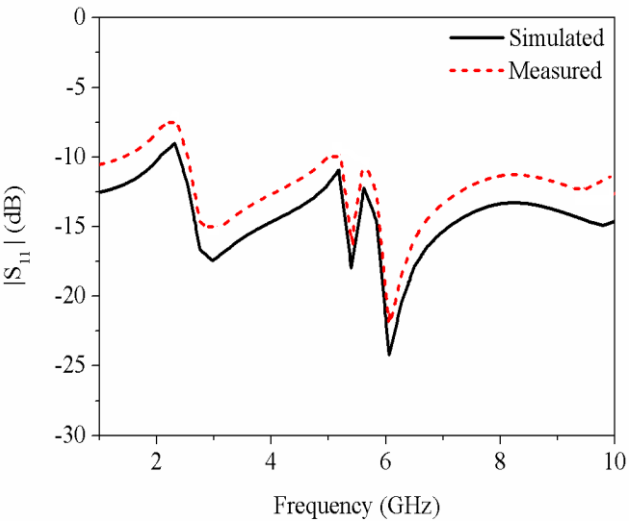


Fig. 5: Simulated and measured S_{11} of proposed antenna configuration

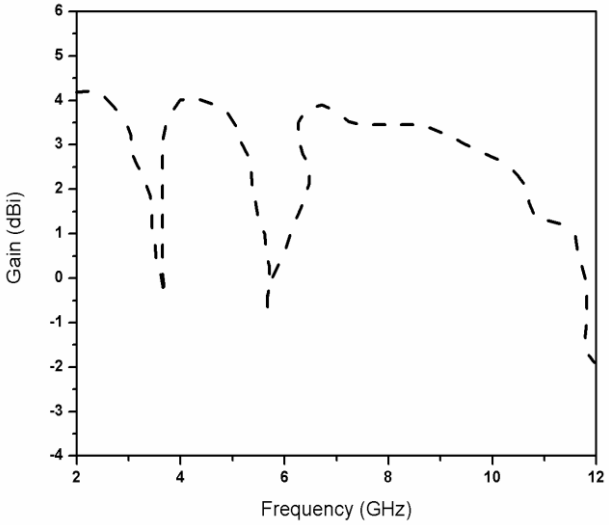
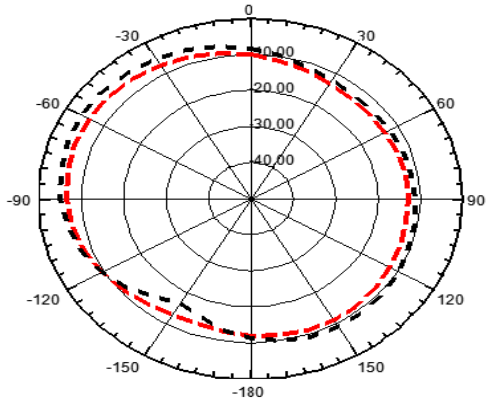
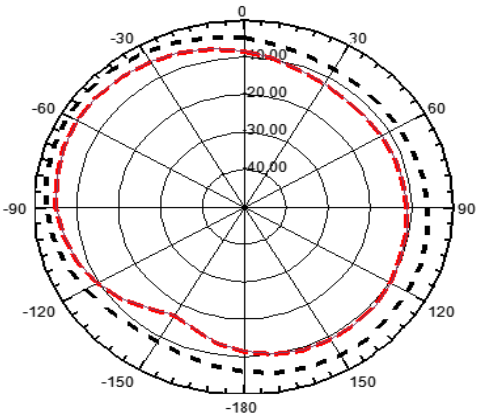


Fig. 6: Proposed Simulated Antenna Gain

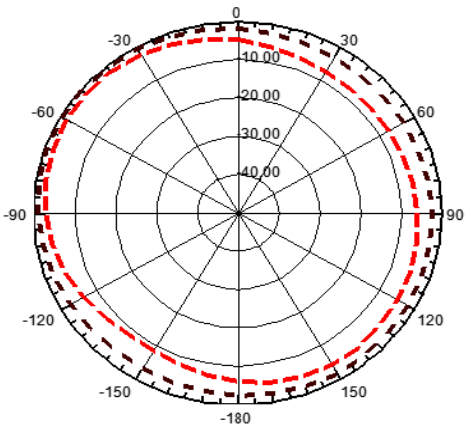
The measurement and testing have been carried out with the help of Vector Network Analyzer. The simulated and measured results of S_{11} are given in Fig. 5. The gain obtained in the simulation of the proposed antenna structure is plotted in Fig. 6, two sharp dips in the maximum antenna gain are observed in the figure at the notch band frequencies. The proposed antenna radiation pattern at various frequencies is represented in Fig. 7 and it is seen that the radiation pattern is look like figure of eight in E-plane and almost omnidirectional in H-plane at three different frequency of 3.1 GHz, 4.4 GHz and 7.1 GHz. Maximum gain achieved is 4 dBi and gain value is slightly decreasing for the case of higher frequency, this is due to high cross polar component in H-plane.



(a)



(b)



(c)

E-plane
H-plane

Fig. 7: Proposed antenna: Simulated Radiation Pattern (a) 3.1 GHz (b) 4.4 GHz, and, (c) 7.1 GHz

4. Conclusion

In this paper, a simple and compact microstrip line fed monopole planar antenna with double stop band behavior is presented. The proposed antenna is easy to fabricate as it simply involves loading of slots. The dual stop band nature is obtained by loading of I-shaped slots, and C-shaped slots with the help of parasitic element of I-shaped on the square patch. Also, modal analysis of variation different slot on characteristics of proposed antenna configuration is also presented. Simulation results have been validated through measurements, which are in good agreement. This proposed structure can be useful for ultrawideband communication applications with good stop band rejection capability.

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