



# DEVELOPMENT OF A BLIND HOLE SUBSTRATE SLOTTED MICROSTRIP ANTENNA FOR X-BAND APPLICATIONS

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**Abstract-** This paper is aimed at developing a blind hole substrate slotted microstrip patch antenna for x-band applications. The proposed antenna has been designed using Rogers RT5880 (lossy) substrate of dielectric constant of 2.2 sandwiched between copper patch and ground plane. The propounded antenna has been devised and simulated in CST Microwave Studio 2014. This antenna resonates at frequency of 10.45 GHz with the minimal return loss of -55.30 dB, high gain of 8.02 dB and directivity of 8.50 dBi. The proposed antenna works for all frequencies from 8 – 12 GHz resulting in a huge bandwidth of 1.1 GHz (9.99 GHz - 11.09 GHz). Bandwidth enhancement of 50 percent is observed in the proposed antenna as compared to the existing antenna. The proposed antenna provides this huge bandwidth with a compact size. The designed antenna can be suitably employed for all X-Band (8-12 GHz) applications including Radar and satellite communications, weather monitoring, military communications, satellite to earth downlink, earth to satellite uplink, radio determination and ultra-wide band applications.

**Index Terms-** blind hole substrate; huge bandwidth; high gain; Earth–satellite uplink; Satellite-earth downlink; X-band; wide-band antenna and slot

## 1. INTRODUCTION

In recent years, wireless communication has been gradually developing and involving innovative wants in antenna technology. Wireless communication has so many applications like WLAN, WIFI, mobile phone, satellite, traffic radar, GPS, military, biomedical and aerospace area that antenna structure is vital part of these systems. Antenna plays the key role of wireless communication from point to the other; it acts as the transducer where it transforms the electrical signal to radio waves, which also helps in conveying the information.

The microstrip antenna (MPA) has been said to be the most innovative area in the antenna engineering. The idea of microstrip antenna was first presented in year 1950s but it only got serious attention in the 1970s. The exceptional features that made the microstrip antenna prominent are relatively easy to construct, light in weight, low in cost and extremely thin protrusion from the surface. These MPAs have a popular frequencies range of above 100MHz. This patch antenna is actually fabricated on a dielectric substrate. The advantage of having this conformable structure is to integrate into various telecommunication systems [1].

The principle of wide bandwidth or bandwidth enhancement of MPAs may be achieved by several efficient approaches such as: Increasing the substrate thickness, Optimizing impedance matching, Reduce substrate effective permittivity, incorporating multiple resonances. In this work a slot creation on the ground elements is utilized to achieve wider bandwidth. Some recent works has been summarized in the Table 1 so as to review the literature and highlight research gap. The summary was presented based on the performance indicators for characterization in terms of antenna gain and bandwidth. Generally, the main limitation of microstrip patch antenna includes low gain and narrow bandwidth. However, some of the already published works in this field include [1-15].

In 2014, a wide band microstrip antenna is designed for Ku band applications with defected ground structure; a circular shape defect is integrated in the ground plane [1]. In the same year, a paper investigate the dependency of antenna parameters designed for 10 GHz inset fed rectangular microstrip patch antenna (RMPA) on varying inset width and inset gap for proper impedance matching so as to have minimum return loss and achieve efficient operation [2]. Also in 2014, a comparative performance study of rectangular and circular shape microstrip patch antennas at an X band frequency, circular patch antenna offers about eight percent higher bandwidth and nearly 2.0dB less side lobe power than that of rectangular patch antenna [3]. Later in 2015, a coaxial probe feed modified swastika shape patch antenna is designed and analyzed to obtain the broadband frequency range in X-band (8-12 GHz) [4]. Also in the same year, a slotted fan shaped microstrip patch antenna with three operating frequencies for radar application is presented; the design model is made to resonate at three frequencies in X-band [5]. In the same year, a Microstrip Patch antenna for radar application is presented, in this paper, conventional shapes like rectangular, triangular and circular microstrip Patch antenna are designed and analyzed at X-band frequency [6]. Also in 2016, a design of a high gain and directivity blind hole substrate slotted microstrip patch antenna for X-band applications was done, the anticipated antenna resonates at frequency of 7.94 GHz with the minimal return loss of -81.25 dB, high gain of 8.5 dB and directivity of

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8.12 dBi with a limited bandwidth; this thesis is aimed at improving [7, 8]. In the same year, a method has been proposed to simultaneously enhance the gain and bandwidth of a microstrip patch antenna [9]. The same year; a design of both planar ultra-wide band (UWB) antenna and UWB antenna with two rejected bands are given, the rejected bands are the WLAN and X-bands, achieved by inserting slots in the patch and the feed [10]. Also in 2016, Also, a novel design of multiband microstrip patch antenna which resonate at 7 unique frequencies between 4 GHz and 14 GHz by inserting a rectangular slot in the ground plane of the patch antenna [11]. Later in 2017, a design of Microstrip Patch Antenna (MPA) using hybrid fractal slot (Koch-Minkowski and Koch-Koch) along with partial ground plane for wideband applications with two resonant frequencies, good gain and bandwidth [12]. In the same year, a combined and compact double H-shaped X-band microstrip patch antenna is designed for bandwidth enhancement [13]. Also the same year, a Hexagonal Patch Microstrip antenna for C Band, X Band and Ku Band Applications with partial and slotted ground plane resulting in a huge bandwidth enhancement of 504 percent [14]. In the same year, a Multiband rectangular shaped Microstrip patch antenna is designed using coaxial feeding techniques which can be used in C & X Band applications [15]. Therefore a small size antenna with a wider bandwidth has been proposed in this work.

**Table-1.1 Literature Mapping**

Author	Substrate Type / Software	Resonant Frequency (GHz)	Bandwidth (MHz / %)	Gain(dB)	Antenna Size(mm <sup>3</sup> )
Mukesh et al, 2014 [1]	FR4 / HFSS	9.8	56.6	5 – 12.88	36x36x0.762
Vinayak et al, 2014 [2]	FR4	10	5 – 8	5.5 – 6	48x18.12x1.5
Tahsin et al, 2014 [3]	DUROID	10	1.04	7.7 – 7.9	8.8x9.95x1.57
Vivek et al, 2015 [4]	FR4 / HFSS	9.5	16.4 – 17.89	4.22 – 4.6	30x30x3
Kiruthika et al, 2016 [5]	FR4 / HFSS	9.9	9.5	1.17 – 3.33	31.31x28.33x1.6
Kiruthika et al, 2016 [6]	FR4/HFSS	9.5	453 – 488	3.67 – 4.31	18.72x16.02x1.6
Divesh et al, 2016 [7]	FR4 / CST	7.9	560	8.5	17.15x33.97x1.57
Divesh et al, 2016 [8]	FR4 / CST	7.9	560	8.5	17.15x33.97x1.57
Muhammad et al, 2016 [9]	DUROID / FR4	60	384 – 1228	13.53 – 13.9	4.44x5.54x0.13
Noor et al, 2016 [10]	FR4 / HFSS			6.1	30x35x1.6
Prema et al, 2016 [11]	FR3.5 / CST	4.5 – 12.6		6.76	55x40x25
Narinder et al, 2017 [12]	FR4 / CST	3.2	2440 – 2660	5.6 – 6.1	45x39x1.6
Jubear et al, 2017 [13]	FR4 / CST	10		5.29	18 x20 x1.6
Shailendra et al, 2017 [14]	FR4 / CST	3.68 – 18.3	504%	4.5	15x20x1.6
Angelin et al, 2017 [15]	FR4 / HFSS	4.4 – 8.4			33.7x38.8x3.2

## 2. METHODOLOGY

### 2.1 Mathematical Formulation of Patch Antenna

A microstrip patch antenna can be conventionally designed using the following equations given empirically by [16] as:

$$\Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3) \left(\frac{W}{h} + 0.264\right)}{(\epsilon_{eff} - 0.258) \left(\frac{W}{h} + 0.8\right)}$$

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Where  $h$  is the substrate thickness and  $W$  is the width of the patch. The effective length of the patch  $L_{eff}$  now becomes:

$$L_{eff} = L + 2\Delta L$$

Where,  $L$  is the patch length.

For a given resonance frequency,  $f_0$  the effective length of the patch is given by as:

$$L_{eff} = \frac{c}{2f_0\sqrt{\epsilon_{eff}}}$$

For a rectangular patch antenna, the resonance frequency is given by [17] as:

$$f_0 = \frac{c}{2\sqrt{\epsilon_{eff}}} \left[ \left( \frac{m}{L} \right)^2 + \left( \frac{n}{W} \right)^2 \right]^2$$

The  $m$  and  $n$  are modes along  $L$  and  $W$  while  $W$  is the width of the patch given by [17] as in equation 5.

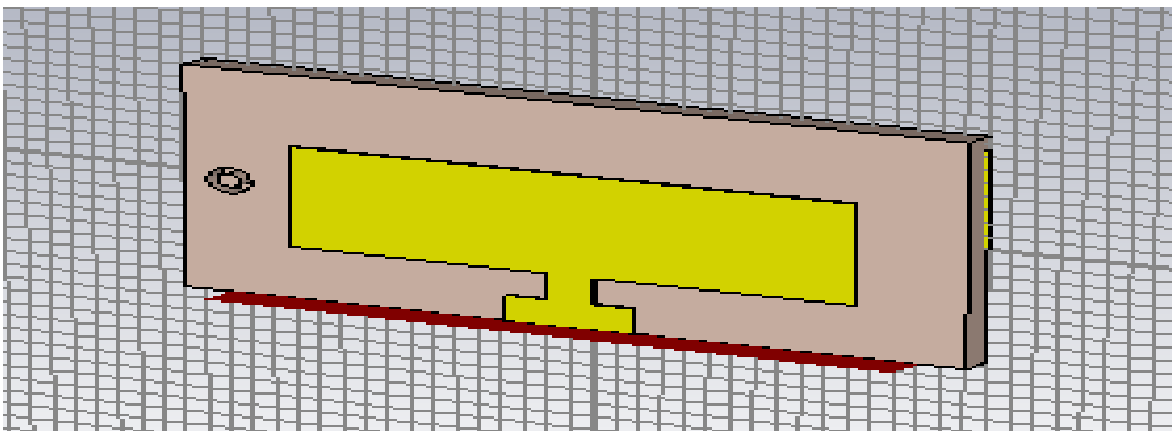
$$W = \frac{c}{2f_0\sqrt{\frac{\epsilon_r+1}{2}}}$$

## 2.2 Design of the Antenna

The design of this microstrip patch antenna based on the equations 1 to 5 of the transmission and the cavity model of microstrip patch antenna. The substrate that was used is RT 5880 and the dimensions of the substrate and the patch are presented in Table 2.2.

**Table-2.2 Antenna Design Parameters**

S. No.	Parameters	Dimensions
1	Ground thickness	0.02
2	Patch thickness	0.13
3	Substrate thickness	1.57
4	Feed length	2.00
5	Patch length	7.73
6	Substrate length	17.15
7	Slot length	6.00
8	Feed width	5.58
9	Slot width	2.00
10	Patch width	0.84
11	Substrate width	2.28
12	Blind hole diameter	2.00
13	Blind hole depth	1.00
14	Distance of blind hole from left	1.99
15	Distance of blind hole from top	8.56



**Fig. 2.1 Design of Microstrip Patch Antenna in CST View (front)**

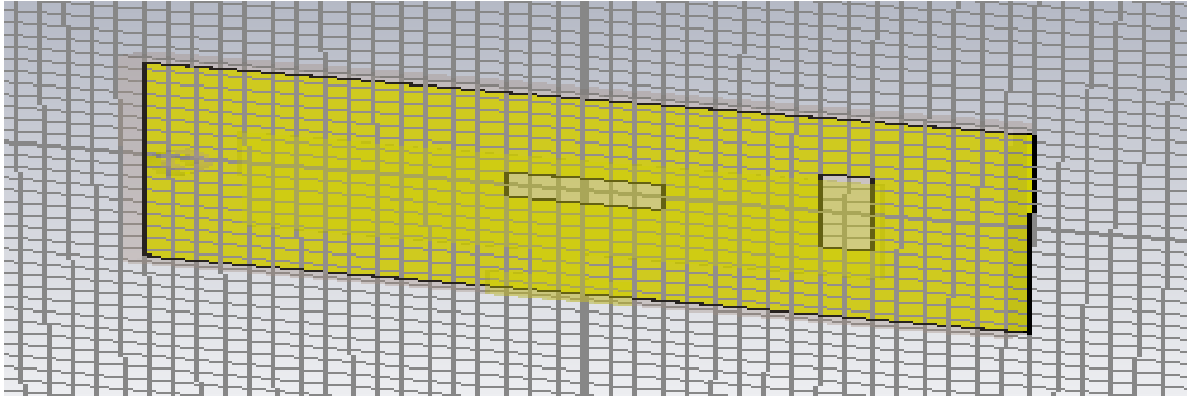


Fig. 2.2 Design of Microstrip Patch Antenna in CST View (back)

### 3. RESULTS AND DISCUSSIONS

The antenna was modeled and simulated using CST studio wave and each layer of the proposed design was assigned with its respective physical and electrical properties. The result of the return loss, VSWR (Voltage Standing Wave Ratio), gain and the radiation pattern of the array patch elements obtained is shown in Figure 3.1-3.3. The patch antenna resonates at 10.45 GHz with a return loss of -55.3 dB as seen in Figure 3 below. The acceptable level of VSWR for wireless application should be less than 2 and as seen in Fig. 3.3, the VSWR of the single patch antenna is 1.00. The antenna achieved a high gain of 8.02 dB with bandwidth of 1.1 GHz that span from 9.99 GHz to 11.09 GHz of mm-wave band which is considered excellent in terms of a compact microstrip patch antenna as shown in Fig 3.1. Also as shown in table 2.2, the antenna size is very small of the precise dimension of 17.15 mm by 33.97 mm by 1.57 mm. The summary of the performance measure of the antenna in terms of gain, return loss, VSWR, and bandwidth were summarized in the Table 3.1.

Table-3.1 Summary of Results

S. No.	Performance parameter	Value
1	Return Loss (dB)	-55.3
2	Bandwidth (GHz)	1.10
3	VSWR	1.00
4	Gain (dB)	8.02

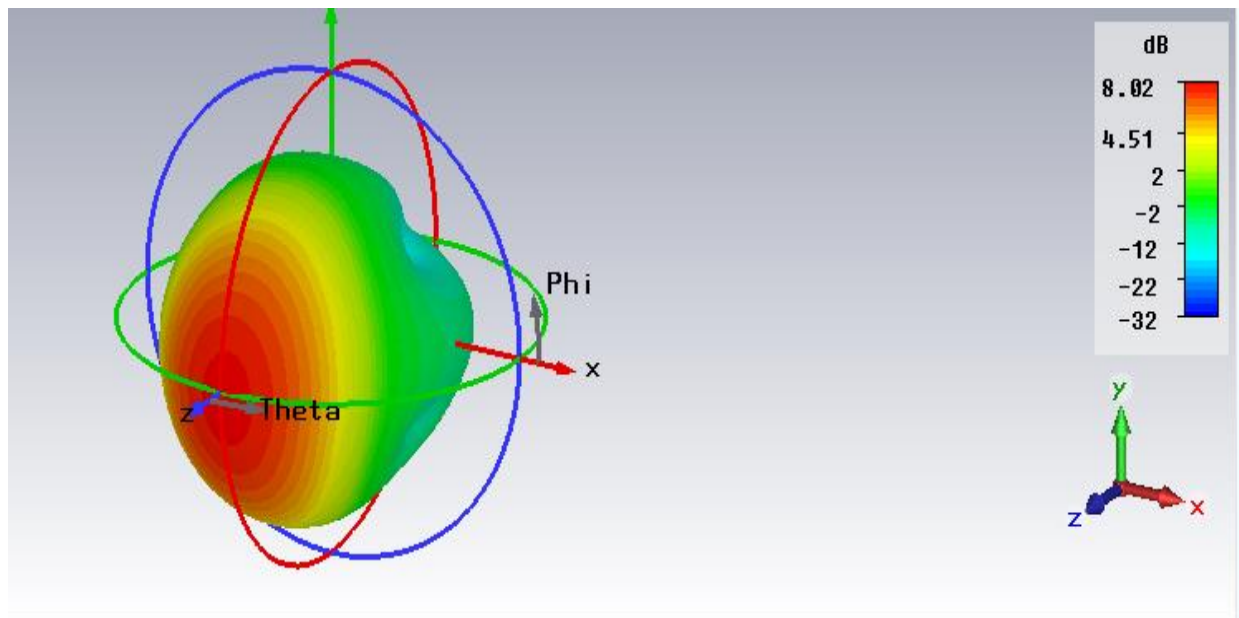
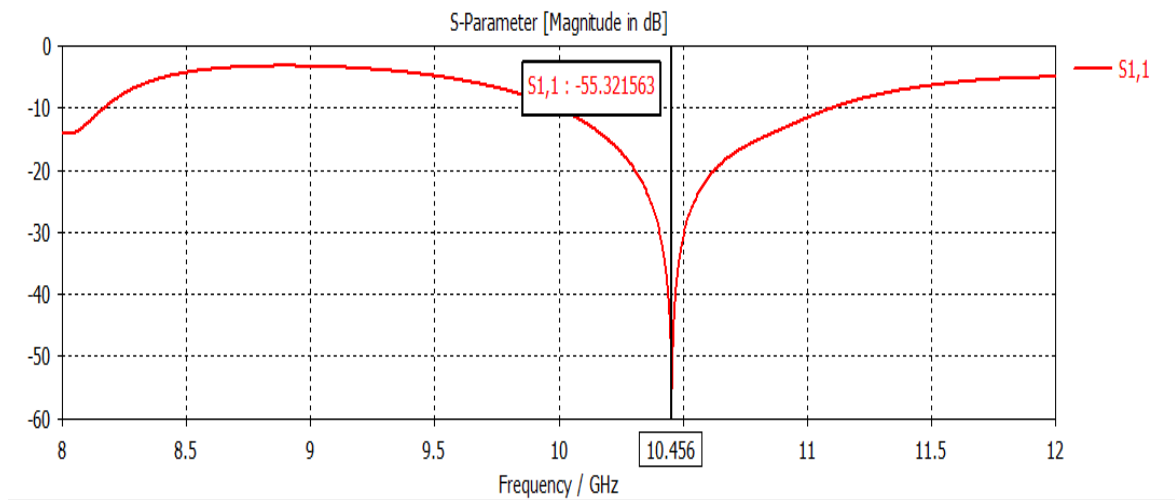
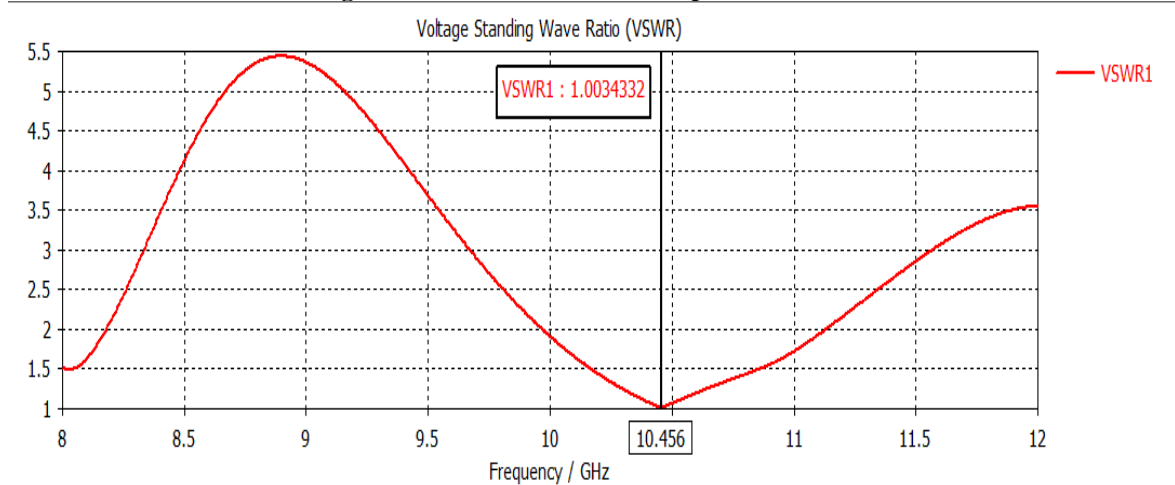


Fig. 3.1 Gain of Microstip Patch Antenna



**Fig. 3.2 Return Loss of Microstrip Patch Antenna**



**Fig. 3.3 VSWR of Microstrip Patch Antenna**

The performance indicators for the antenna are summarized in Table 3.2 to highlight the contribution of this work. It could be observed from Table 5 that there is improvement in terms of bandwidth from 0.56 GHz to 1.10 GHz but the gain of the proposed work is 8.02 dB, which is a little less than that of the existing work. This is usually the case in antenna design of a usual trade-off between gain and bandwidth.

**Table-3.2 Comparison of Proposed Work With the Existing**

Parameter	Proposed Work	Existing Work
Bandwidth (GHz)	1.10	0.56
VSWR	1.00	1.7
Return Loss (dB)	-55.3	-81.3
Gain (dB)	8.02	8.50

## CONCLUSION

The proposed antenna shows good results in terms of bandwidth. A huge increment of 100% is observed in the proposed antenna. The proposed antenna covers the X- band satellite communication applications. The specified frequency ranges can also be employed for military satellite, military and government institutions for weather monitoring, air traffic control, maritime vessel traffic control, radio-determination purposes, defense and tracking vehicle speed detection for law enforcement. Further work will be the fabrication of the simulated design to validate the results.

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