A Square Shaped Antenna with U and Inverted U-shaped Slots for Multiple Wireless Applications

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ABSTRACT

This paper intends to provide a design and analysis of a square compact super wideband (SWB) antenna which has a good fractional bandwidth. The antenna design is based on 25mmx25mmx1.6mm dimensions with a defected ground, four U-shaped slots are provided in the ground to increase its efficiency and the patch is provided with three U-shaped slots. The design is made simple to implement with a simple design for which the impedance bandwidth >165% (2.55GHz- 26.1GHz).

Keywords— Fractional bandwidth, impedance bandwidth, defected ground, SWB, U-shaped slot

I. INTRODUCTION

In a long run the design of antenna has been always a challenge. Wideband antennas have always given an edge to use antennas for various applications which are secure and can transfer the data at high rates. First it was only wideband antenna which was only used for few applications like GSM, Bluetooth etc. and then it was categorized as UWB and SWB. As the research progressed and more and more BW of GHz was made available, the research begun on UWB antennas that gave a major breakthrough in the design until it was regulated under the frequency band of 3.1GHz to 10.64GHz [12]. UWB is still a part of research for the design of compact antenna which can perform even better. UWB is having a great advantage of using less power thus being power efficient, UWB were actually designed for high data rates for short ranges and were able to transfer data at low rate for long range.

As the demand for high data rates increased even for long ranges especially WPAN which demand high data rates for short and long ranges, work begun on SWB antennas which led to fulfillment of this requirement. Researchers amid their work on SWB antennas and produced their results for compact design. The frequency range for SWB antennas is not fixed; it can start from any point in the GHz frequency range and extend beyond 10.6 to increase BDR. There are still few papers in SWB part and the field is open for the researchers. SWB antennas due to high bandwidth ratio are even best suited in multi propagation and can avoid jamming.

A good design will include ultra wideband, super wideband and even the frequencies below 3.1 GHz for using a single device for various applications with a compact development. The other applications include WIMAX, WLAN, Bluetooth, GSM and handheld device applications. Table 2 gives the comparison of various designs in terms of fractional bandwidth and reduction in size. Working on a design which can include all the above applications with a good design in comparison to the other can lead to a good progress in the field of antennas and can have a great effect in the field of sensors too, which also demand the transfer of data at high rates in short and long ranges. The designed model gives a better performance, high BDR (2.55GHz-26.1GHz) and has small size as compared to referred models.

II. ANTENNA DESIGN

The main objective of the proposed research article is to design a compact super wideband antenna with stable radiation performance and gain. In order to achieve this aim the antenna is designed with defected ground and U-slots (i.e. three slots in patch) as depicted in fig.(1)&fig.(2). The dimensions obtained from these calculations are optimized to get the desired frequency of operations. The simulated S_{11} of the designed antenna is shown in

Fig.3. It can be seen that the antenna shows different bands of operation around 11GHz to 25GHz. In order to get this operation slotting is also done in the ground plane which can be observed from the Fig.2.

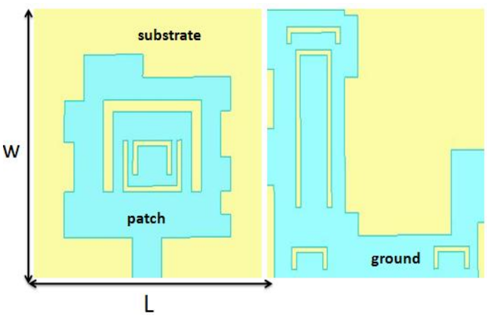


Fig.1 proposed antenna design

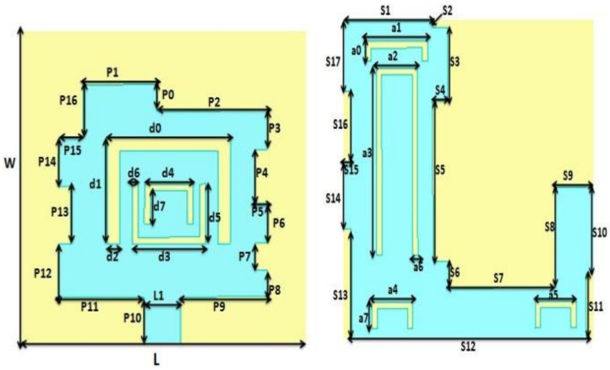


Fig.2 Detailed dimensional view of proposed design

The introduction of U-shaped slots affects the surface current distribution, thereby increasing the current length path thus making the antenna to resonate at 3.49, 10.82, 12.62, 13.93, 14.81, 17.00, 20.08, 22.5, 25.07GHz. In general the proposed antenna structure consists of unsymmetrical patch with U-slots as radiating element and inverted U-slots with rectangular slits on the ground plane, 25mmx25mm reduced antenna with a good result is provided. The dimensional analysis is shown in table 2.

The slots are made to increase the BWR. The first U-slot increases the BW by 6%, second increase the BW by 25% and the other slot increase the BW by 30%. The ground inverted slots help to increase the further resonance BW. Thus in this way proposed antenna provides more than a decade BW. Inverted U-slots in the ground are cut to distribute the current distribution and hence minimize the size of the ground plane which results in the increase in impedance BW. The dimensions of the antenna are listed in the table 1. The antenna is printed on the FR-4 substrate which is cost effective and readily available, with a thickness of 1.6mm.

2.1 Design Equation

The antenna is designed using set of equation (1)-(2)-(3).

The length (L_0) of the radiating part is calculated as (1).

$$L0 = \frac{C}{2f_0\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W_2}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W_2}{h}+0.8\right)}\right) \qquad (1)$$

The width (W_0) of the radiating patch is calculated as (2).

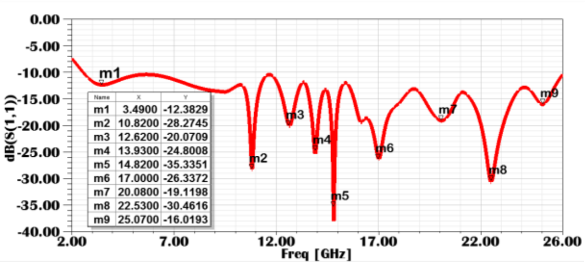
$$W_0 = \frac{C}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \qquad (2)$$

The antenna feed width $(L1)$is calculated as (3).

$$\frac{L1}{h} = \frac{8\exp(A)}{\exp(2A)-2} \qquad (3)$$

III. RESULTS

The entire analysis of the antenna is carried out on HFSS v.13.0. The substrate material used for the antenna design is FR-4 with $\varepsilon_r = 4.4, h = 1.6, \delta = 0.002$. Lumped port excitation method is used to energize the antenna. The proposed structure has a volume of 1000mm^3$(25 \times 25 \times 1.6mm^3)$. The proposed antenna is printed on FR-4 substrate with thickness of 1.6mm. Antenna dimensions are summarized in table1. 50 ohms micro-strip line is used to feed the antenna, simulations are carried out using HFSS software. Simulated results of s_{11} (Fig.3) and VSWR<2 (Fig.4) are shown. The figure illustrates s_{11} below -10db which extends from 2.5GHz to 26.1GHz, also VSWR<2extends from 2.5GHz to 26.1GHz that corresponds to significant BW evaluated after the three defects are inserted in the patch in the form of triangular U-slots and the BWR is increased to the max level of 26.1GHZ. Both the graphs show a good agreement.



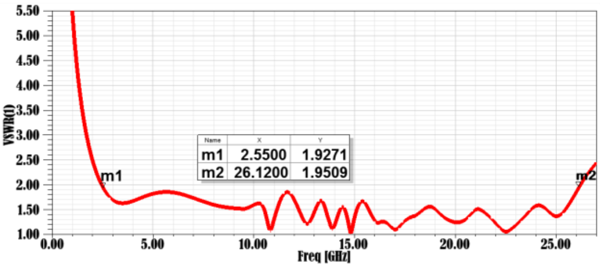


Fig.3 S_{11} plot of the proposed configuration Fig. 4 VSWR of the proposed configuration

Impedance of the proposed antenna is also shown in the figure 5; both imaginary values and real ones are marked The antenna has input impedance of $(48.03 + j24.19$, $(50.24 + j3.88)$, $(60.96 - j1.02)\Omega$, $(47.4 + j5.24)\Omega$, $(53.78 + j3.25)\Omega$, $(44.14 + j8.66)\Omega$, $(49.79 + j2.92)\Omega$ and $(47.43 + j15.38)\Omega$ at the resonance frequency of 3.49, 10.82,12.62,13.7,14.81,16.25,16.96,20.08, 22.5 and 25.07 GHz respectively.

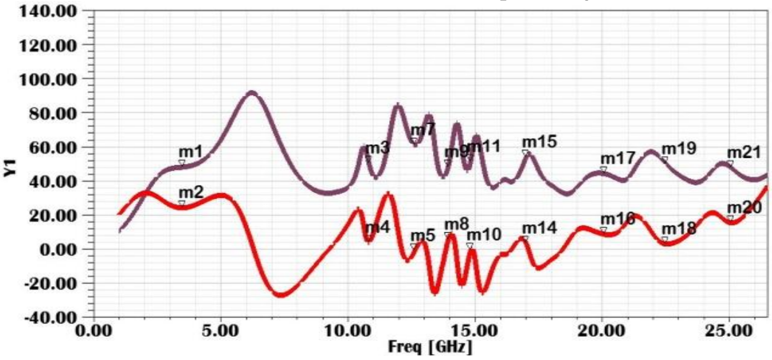
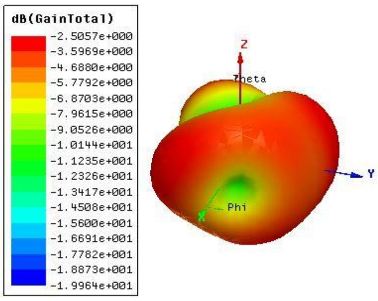
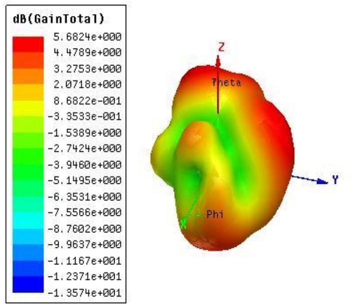


Fig.5 impedance plot of the proposed configuration

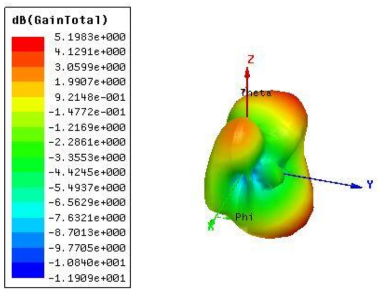
The gain of the proposed antenna is shown in Fig.6. It can be seen that the gain of the antenna varies from 3.33db to 8.07db with 3.33db at 6GHz and 8.07db at 25.07GHz, at other resonating frequencies gain varies from 4.11db to 5.97db.



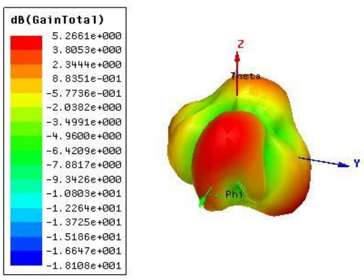
(a)



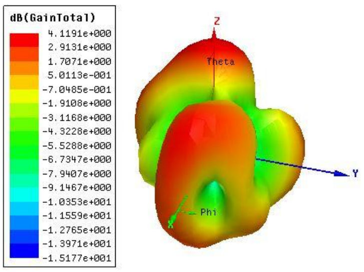
(b)



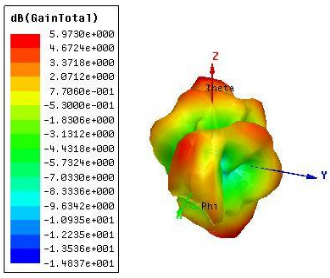
(c)



(d)



(e)



(f)

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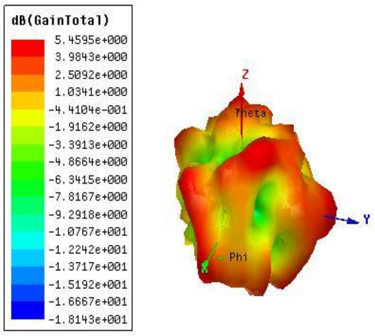
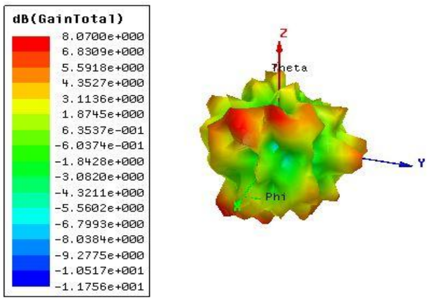


(g)



(h)

Fig.6 gain plot for (a) 3.49, (b) 10.82, (c) 12.62, (d) 13.93, (e) 14.81, (f) 17, (g) 20.08 and (h) 25.07 GHz

Table 1: Detailed dimensions of Proposed SWB Antenna

Detailed dimensions of Proposed SWB Antenna						
W=L=25mm	P1=6mm	P2=9mm	P5=d2=1mm	d5=4.5mm	P0=P7=2mm	P8=P15=2mm
P9=P11=7mm	d4=P4=4mm	P16=P10=4mm	P12=a4=4mm	d7=P3=3mm	P6=L1=3mm	S2=a6=0.5mm
d0=10mm	d1=8mm	d3=6mm	d6=0.5mm	S1=9mm	S3=5.5mm	S3=5.5mm
S4=1.5mm	S5=12mm	S6=2mm	S7=10.5mm	S8=7.5mm	S9=4mm	S10=6.437mm
S11=5mm	S12=23mm	S13=8.5mm	a0=1.5mm	a1=6mm	a2=4mm	a3=14mm

Table 2: Comparison of proposed antenna with previously reported antennas

Reference	Dimensions	Fractional BW%
[1]	31mmx45mm	181
[2]	77mmx35mm	172
[3]	120mmx140mm	182
[4]	135mmx90mm	183
[10]	55mmx38mm	168
[11]	60mmx60mm	133
[9]	150mmx150mm	189
[6]	45mmx30mm	164
[5]	40mmx30mm	163
Proposed	**25mmx25mm**	**166**

V. CONCLUSION

In general the proposed antenna is best suited for SWB applications with higher gain at higher frequencies above 10GHz as can be seen from the figure above having most of its resonating frequencies between 10 to 25GHz. The antenna can even be notched at some frequencies to avoid interference for a particular application. Antenna also exhibits significant radiation pattern and is having a suitable gain covering a larger bandwidth.

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