International Journal of Engineering & Technology, 7 (3.6) (2018) 45-47

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Design of a Square-Shaped Broadband Antenna with Ground Slots for Bandwidth Improvement

K.M. Jyothsna[1*], S. Suganthi[2]

[1]*M.Tech- Scholar, Department of Electronics and Communication, Faculty of Engineering, Christ (Deemed to be University), Bangalore, India.*
[2]*Professor, Department of Electronics and Communication, Faculty of Engineering, Christ (Deemed to be University), Bangalore, India.*
E-mail:drssuga@gmail.com
**Corresponding author E-mail:jyothsnakm111@gmail.com*

Abstract

This paper portrays the design of a compact square-shaped microstrip broadband antenna using ground slots. Polygon shaped slots are placed on the ground under the feed line for bandwidth improvement. Similarly, rectangular slots are placed on the square patch for gain enhancement. Effect of these slots on the performance of the antenna in terms of impedance bandwidth, gain and directivity are studied. Results of simulation tests show that a ground slot with proper dimensions placed under the feed line can improve the impedance matching and hence increase the bandwidth without affecting much the performance of the antenna. This compact antenna of size 9.098 x 9.098 mm can be very useful for applications where size is a major constraint. Simple microstrip feed is used to feed the patch. The percentage bandwidth of this antenna is 75.57 %.

Keywords: *Broadband antenna, microstrip feed, ground slots.*

1. Introduction

Microstrip antenna has attracted much attention by virtue of its numerous advantages like low cost, lightweight, high gain, compactness and ease of fabrication [1]. Despite all these advantages, microstrip antennas exhibit an inherent narrow bandwidth[2]. The advent of the broadband system in wireless communication area has demanded the design of antennas that must operate effectively over a wide range of frequencies[3]. An antenna with wide bandwidth is referred to as a broadband antenna. Several techniques have been proposed to increase the bandwidth of an antenna. Few such techniques are widening the patch, increasing the thickness of the substrate and introducing ground slots. Ground slotting technique is exploited here as it enables bandwidth improvement without increasing the volume of the antenna as in the other methods[4].

In this work, we demonstrate the design of a compact square-shaped broadband antenna using ground slots. The designed antenna was simulated using Ansoft HFSS software for parametric analysis. Different parameters like return loss, directivity, gain, and VSWR values were analyzed. Stage by stage improvement in the design and its corresponding parametric changes has been explained in detail.

2. Antenna Design

Figure 1 shows the HFSS design of the proposed broadband antenna. Narrow slots in the patch are also shown in the figure. This broadband rectangular patch has been placed on a substrate of thickness 1.6 mm and ε_r value 4.2. The antenna was designed for a frequency of 7.5 GHz. The patch dimensions were calculated using the basic design equations (1)-(5) given below [5-8].

$$Wp = \frac{c}{2*fr*\sqrt{\frac{\varepsilon r+1}{2}}} \quad (1)$$

$$Lp = Leff - 2\Delta L \quad (2)$$

$$where\ Leff = \frac{c}{2*fr*\sqrt{\varepsilon eff}}$$

$$\Delta L = \frac{(.412*h)(\varepsilon eff+0.3)(\frac{W}{h}+.264)}{(\varepsilon eff-0.258)(\frac{W}{h}+0.8)} \quad (3)$$

$$Ws = Wg = (6*h) + Wp \quad (4)$$

$$Ls = Lg = (6*h) + Lp \quad (5)$$

Where, f_r =Resonant frequency, W_p = Width of the patch, L_p =Length of the patch, W_s = Width of the substrate, L_s= Length of the substrate, W_g=Width of ground, L_g= length of the ground and ΔL = extension of length.

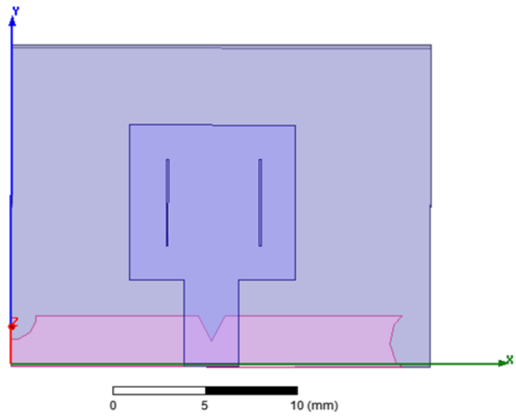


Fig. 1: The view of proposed broadband antenna

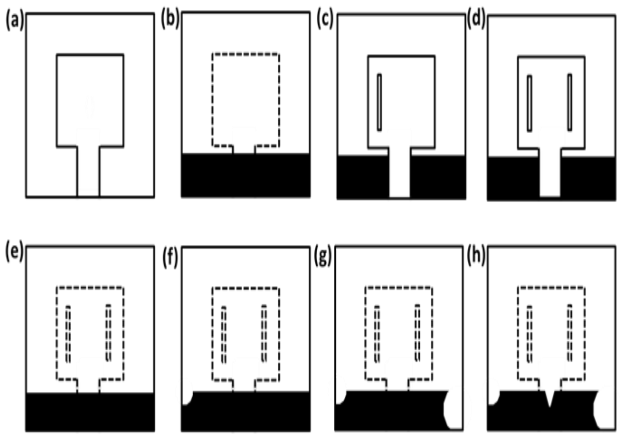
Table I: Dimensions Used for Antenna Design

Design parameters	**Dimensions (mm)**
Length of Patch L_p	9.098
Width of patch W_p	9.098
Length of feed L_f	4.87
Width of feed W_f	3
Length of substrate L_s	18.69
Width of substrate W_s	23
Thickness of substrate h	1.6
Length of ground L_g	3
Width of ground W_g	23

The values obtained after substituting in the above equations are as follows. W_p=9.098 mm, L_p=9.098 mm, L_f=4.8795 mm, W_f=3 mm, W_g=23 mm, L_g=18.6955 mm, L_s=18.6955 mm, W_s=23 mm. The width W_p of the patch was made equal to the length of patch L_p to make the patch more compact and square in shape. This conventional square patch antenna was further modified by insertion of slots in the ground plane and patch, which enhanced the bandwidth and gain of the antenna. Table 1. shows the dimensions used in the final antenna design.

Fig. 2 shows the stage by stage modifications done on the conventional antenna. Fig. 2. (a) shows the design of conventional square-shaped patch antenna with a very low bandwidth of 2.6 GHz operating at 15.4 GHz. A ground slot was introduced below the patch in the second stage as shown in fig. 2. (b), which improved the bandwidth of the antenna from 2.6 GHz to 3.2 GHz. In stage 3, a narrow slot of 0.1 mm thickness and length 5.089 mm was added to the previous design, which slightly enhanced the gain of the antenna from the previous design. In stage 4, one more slot was made on the patch of the same dimension. This further enhanced the gain of the antenna. At this stage, antenna operates in a low-frequency range of 5.7 to 9 GHz with an appreciable bandwidth of 3.3 GHz. This particular configuration can be used for low-frequency operations.

Later, the ground height was further reduced by 1 mm, which resulted in a significant improvement in the antenna bandwidth. But, this shifted the resonant frequency of the antenna into a higher frequency range. Now antenna operates in a frequency range of 5.6 to 13.4 GHz with a bandwidth of 7.8 GHz. Reduction in gain and directivity was observed in the new configuration when compared to the conventional design. Thus, in further stages several slots were inserted in patch and ground to enhance the gain and directivity of the antenna. In stage 6, a polygon-shaped slot of radius 0.1 mm was made in the ground plane which enhanced the gain, directivity and returns loss of the broadband antenna. In stage



7, an additional dodecagon slot of slightly higher radius, 1.5 mm was placed on the slotted ground for enhancing the gain and bandwidth. In the final stage, a triangular shaped slot was added on the ground plane to further enhance the gain and directivity. Table 2. shows the detailed parametric improvement for all eight stages of design. In table, BW: bandwidth; f_r: Resonant frequency; VSWR: Voltage Standing Wave Ratio.

Fig. 2: Different stages of broadband antenna design (a)-(h) show the 8 stages of antenna design. (b), (e), (f), (g) and (h) highlights the back view of the antenna thus, the patch and feed are represented using the dashed line.

Table II: The improvement in Antenna Parameters during Each Stage of Modifications

Stage	**f_r (GHz)**	**BW (f_H-f_L) (GHz)**	**VSWR**	**Gain (dB)**	**Directivity (dB)**
1	15.4	2.6 (14.6 -17.2)	1.03	5.28	7.21
2	7	3.2 (5.8-9.0)	1.5	2.35	2.69
3	7	3.3 (5.7-9.0)	1.25	2.39	2.31
4	7	3.3 (5.7-9.0)	1.36	2.45	2.61
5	11	7.8 (5.6-13.4)	1.02	2.12	2.36
6	10.2	7.8 (5.6-13.4)	1.03	2.27	2.49
7	10.8	7.8 (5.6-13.4)	1.05	2.35	2.58
8	10.3	7.8 (5.7-13.5)	1.05	2.41	2.63

3. Results and discussion

The broadband antenna was designed and simulated using ANSOFT HFSS (High-Frequency Structure Simulator), with a sweep range of 0-15 GHz. The designed antenna operates at a frequency of 10.3 GHz with a bandwidth of 7.8 GHz. The antenna exhibited a better performance in terms of bandwidth when slots were introduced in the ground plane. The fig. 3 shows plot showing the return loss of the broadband antenna. From the figure, it's clear that the antenna operates in the frequency range of 5.7 to 13.55 GHz. The antenna provides a very low return loss of -39 dB and a gain of 2.6 dB. The minimum return loss value showed the high impedance matching of the antenna. The percentage bandwidth of the final design is 75.57 %.

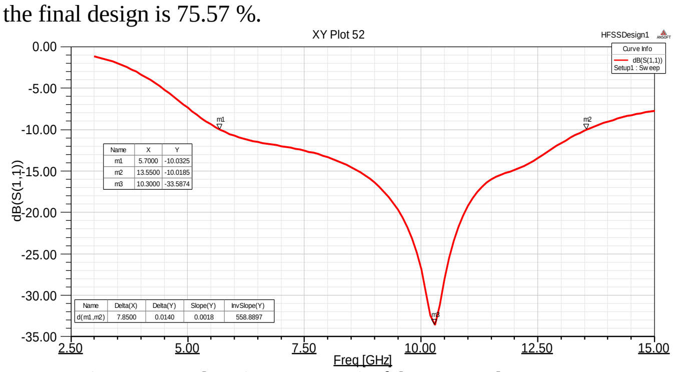


Fig. 3: Return loss (S_{11} parameter) of the proposed antenna

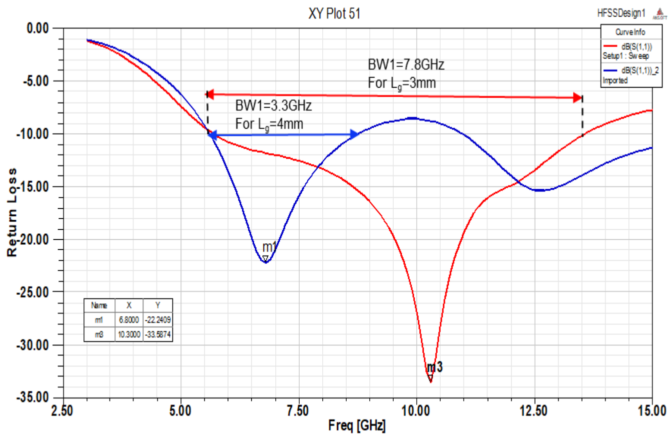


Fig. 4: Graph comparing the Return loss of two selected stages. The dashed line shows the line corresponding to -10dB.

There was a notable increase in the bandwidth of the antenna from 3.3 GHz to 7.8 GHz with the reduction of height of the ground plane by 1 mm. This is explained by the overlapped graph shown in figure 4. From the fig, BW1 represents the bandwidth of 3.3 GHz for a ground length of 4 mm and BW2 represents the bandwidth of 7.8 GHz for a ground width of 3 mm. This highlights the importance of ground slotting in bandwidth improvement. The ground slots are always made in such a way that they lie below the patch of the antenna.

Voltage Standing Wave Ration (VSWR) value was examined to evaluate the power reflected from the antenna. The smaller the VSWR value, better is the matching and least the reflection. The ideal value is 1, where there is no reflection from the antenna. The

VSWR plot for the final antenna design is shown in fig. 5. The antenna maintained a VSWR value between 1 and 2 within the full range of operation and at operating frequency of 10.03 GHz, it showed a VSWR value of 1.03. This validates the impedance matching of the proposed broadband antenna. The antenna also provides a total gain of 2.412 dB and total directivity od 2.6 dB , which is shown in fig. 6.

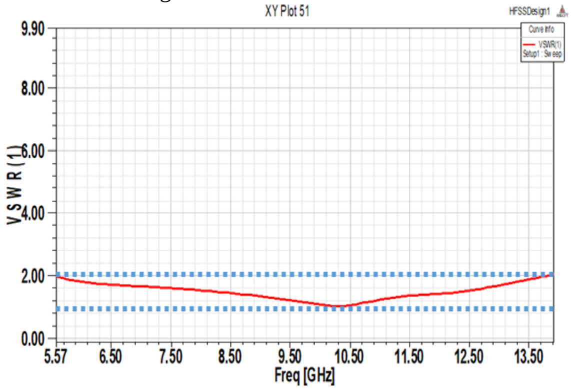


Fig. 5: VSWR plot of the proposed antenna. The blue colored dashed line shows a VSWR value corresponding to 1 and 2.

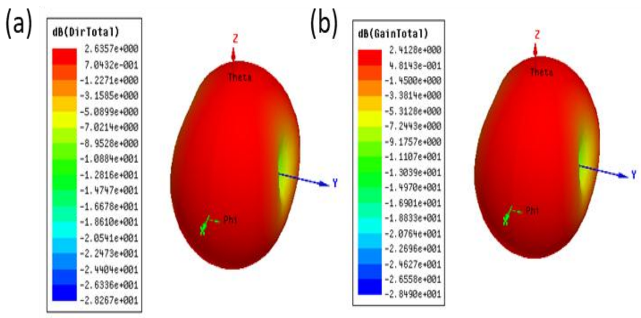


Fig. 6: 3D polar plot of directivity and gain of the proposed antenna. (a) Total directivity of (b) Total Gain

4. Conclusion

A numerical characterization of a square patch antenna for broadband applications was presented and discussed here. HFSS software was used for the parametric analysis. The use of the slotted ground planes resulted in broadband characteristics for the investigated antenna geometry. The insertion of narrow width slots in the patch enhanced the gain of the antenna. Similarly, insertion of slots in ground plane enhanced the gain and directivity of the antenna. This compact broadband antenna can be used for applications which demand large bandwidth where size is a major constraint.

Acknowledgment

The author[1] places her record of gratitude for the facility provided by the RF & Microwave Research Laboratory of Christ (Deemed to be University) funded under Major Research Project (MRP).

References

[1] Singh I & Tripathi V, "Micro strip patch antenna and its applications: a survey", *Int. J. Comp. Tech. Appl*, (2011), pp.1595-1599.

[2] Thorat SS, Jaiswal RC, Rajkumar D & Lokhande DS, "Efficient techniques for bandwidth improvement of microstrip patch antenna", *IRA CST-International Journal of Computer Networks and Wireless Communications (IJCNWC)*, (2012).

[3] Gupta NP, Maheshwari R & Kumar M, "Advancement in ultra wideband antennas for wearable applications", *Int. J. Sci. Eng. Res.*, (2013), pp.341-348.

[4] Kumar R, Shinde J & Uplane M, "Effect of slots in ground plane and patch on microstrip antenna performance", *International journal of recent trends in engineering*, (2009), pp.34-36.

[5] Afridi MA, "Microstrip patch antenna−designing at 2.4 GHz frequency", *Biological and chemical research*, (2015).

[6] Sivakumar E, Srinivasa Rao O & Manikandan A, "Bandwidth Enhancement of Rectangular Microstrip Patch Antenna using Slots", *IQSR Journal of Electronics and Communication Engineering (IQSRJECE)*, (2013), pp.07-10.

[7] Jose SK & Suganthi S, "Rectangular microstrip antenna for WLAN application", *International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS)*, (2015).

[8] Roy AA, Mom JM & Igwue GA, "Enhancing the bandwidth of a microstrip patch antenna using slots shaped patch", *American Journal of Engineering Research*, (2013).