Design of a Frequency Notch Band Stepped Rectangular Microstrip Antenna

Annapantula Sudhakar, Telagarapu Prabhakar

Abstract: ***The intention of this paper is to propose and explore a frequency notch band stepped rectangular microstrip antenna ranging from 4 to 11 GHz. First design is about UWB antenna with a frequency range from 4.3 to 10.9 GHz and second design deals with frequency notched antenna ranging from 4 to 11 GHz with a stop band from 4.4 to 4.8 GHz. It is required to stop the frequency band from 4.4 to 4.8 GHz used for receiving the frequencies of INSAT as it is overlapping the UWB range. The notch band is due to the introduction of U shaped slot on patch of FR4 substrate. By changing the dimensions of the slot and ground height, the frequency response can be altered. Simulation of the suggested antenna is done by HFSS software. Graphs for the return loss, VSWR, Radiation patterns are illustrated to support the behavior of the antenna.***

Index Terms**:** ***Microstrip antenna, Notched band, Return loss, frequency response.***

I. INTRODUCTION

Because of the advantages of the microstrip antennaa, they are gaining the popularity. They are low cost, easily fabricated and conformal antennas [1]. Wide bandwidth can be obtained by having corners cut at the bottom of rectangular patch [2]. Copper layer is coated on both the sides of FR4 substrate and the required shapes can be etched as per our requirement. In the first design no slots were etched to get UWB range and the second design deals with frequency notched band antenna. Any determined shape can be used as the patch depending on application and other side used as ground. The effect of slots is discussed in detail in [3].

Frequency band from 4.4 to 4.8 GHz is allotted for reception of frequencies of INSAT. Band notch filters are required to reject the INSAT reception band from UWB band. Notch properties are realized by C shaped slot on radiating element [4], H and C shaped slots [5], loading of resonant slot [6], Combination of rectangular SRR and inverted L-strip to get rejection bands from 5.1-5.7 GHz and 7.2-7.8 GHz respectively [7], vertical strip offside to the microstrip feed [8] and different shapes of slits etched on the patch [9]. The suggested antenna is suggested for UWB applications with frequency notch of INSAT reception band of 4.4 to 4.8 GHz. The benefit of the suggested antenna is that it is smaller than some of the antennas described above.

Manuscript published on 28 February 2019.
***** Correspondence Author (s)
A. Sudhakar*, Department of ECE, GMR Institute of Technology, Rajam, India
T. Prabhakar, Department of ECE, GMR Institute of Technology, Rajam, India

II. ANTENNA DESIGN

Antenna design consists of two steps. In step 1, UWB antenna of 12 × 20 × 1.6 mm^3 is proposed as shown in Fig. 1(a) with frequency range from 4.3 to 10.9 GHz. It has a stepped rectangular patch fed with microstrip line of 6.2 x 2 mm^2 on front of FR4 substrate. Height of ground plane is 3 mm. U shaped slot is etched on patch to introduce notched band as shown in Fig 1 (b). The dimensions of the U slot on patch are optimized to have frequency rejection characteristics. The thickness, relative permittivity and loss tangent of FR4 substrate are 1.6 mm, 4.4 and 0.02 respectively.

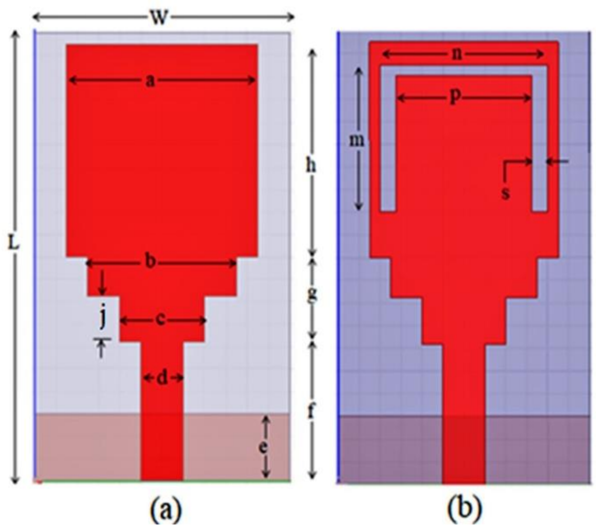

Fig. 1. Suggested antenna (a) Without slot (b) With slot

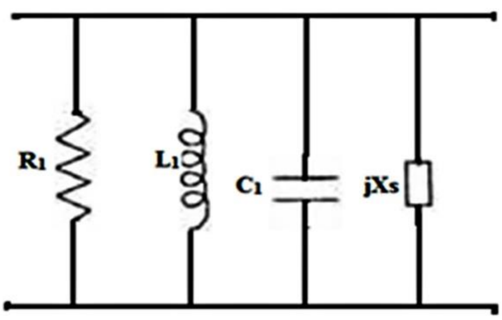

Fig. 2. Equivalent circuit

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

The expressions of R_1, L_1 and C_1 is given by [10]

$$C_1 = \frac{\varepsilon_0 \varepsilon_e LW}{2h}\left(\cos\frac{\pi x_0}{L}\right)^{-2}$$

$$L_1 = \frac{1}{W^2 C_1}$$

$$R_1 = \frac{C\sqrt{\varepsilon_e}}{4WC_1 fh}$$

Width of the patch is calculated by

$$W = \frac{c_0}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}}$$

Effective dielectric constant is calculated by

$$\epsilon_{reff} = \left(\frac{\epsilon_r+1}{2}\right) + \left(\frac{\epsilon_r-1}{2\sqrt{1+12\frac{h}{w}}}\right) \quad W/h > 1$$

Length extension is given by

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

Length of patch (L) is given by

$$L = \frac{c_0}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L$$

The width of the 50Ω microstrip feed line (W) can be found using

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{reff}}\left[\frac{W}{h}+1.393+0.667\ln\left(\frac{W}{h}+1.444\right)\right]} \text{ for } \frac{W}{h} > 1$$

Table 1. Dimension of suggested antenna

Parameters	Value (in mm)
W	12
L	20
a	9
b	7
c	4
d	2
e	3
f	6.2
g	3.8
h	9.75
j	2.05
m	6.5
n	8
p	6.5
s	0.75

III. RESULTS AND DISCUSSION

Suggested antenna operates in the range of 4 -11 GHz with 4.4 – 4.8 GHz rejection. High Frequency Structure Simulator (HFSS) is used to simulate the suggested design. The reflection coefficient vs. frequency graph is shown taking the reference as -10dB in Fig. 3. Blue color is showing the response for antenna without U shaped slot and red color is showing the response for U shaped slotted antenna. It is clear from the figure that U slot introduces the stop band.

The length of the U slot is given as

L_{slot} = 2m + n + (n-p) which gives around 19.5 mm.

Notch frequency is calculated by

$$f_{notch} = \frac{300}{2(L_{slot})\sqrt{\varepsilon_{reff}}} = 4.68 \text{ GHz}$$

where $\varepsilon_{reff} = \frac{\varepsilon_r+1}{2}$

f_{notch} is the center frequency of the notched band in GHz.

The slot is taken as a capacitive reactance on the patch.

$$C_1 = \frac{\varepsilon_e \varepsilon_0 LW}{2h}\cos^{-2}\left(\frac{\pi z_0}{L}\right)$$

h = Thickness of substrate

ε_e= Effective dielectric constant

ε_0 = Permittivity of free space

z_0= feed point location along z- axis

$$L_1 = \frac{1}{C_1\omega_r^2}$$

$$R_1 = \frac{Q}{\omega_r C_1}$$

The input impedance of the circuit excluding slot is expressed as

$$Z_{in} = \frac{1}{\frac{1}{R_1} + j\omega C_1 + \frac{1}{j\omega L_1}}$$

$$= \frac{(\omega L_1)^2 R_1 - j R_1^2 \omega L_1(\omega^2 L_1 C_1 - 1)}{(\omega L_1)^2 + R_1^2(\omega^2 L_1 C_1 - 1)^2}$$

The above equation can be expressed as

$Z_{in} = R - jX$

Where R and X are tge real and imaginary part of Z_{in} respectively.

The input impedance of the slot loaded patch is expressed as

$$Z_{ins} = \frac{(R-jX)(jX_s)}{R - jX + jX_s}$$

$$= \frac{X.X_s + jR.X_s}{R - j(X - X_s)}$$

Using this value, the reflection coefficient is expressed as

$$(\Gamma) = \frac{Z_0 - Z_{ins}}{Z_0 + Z_{ins}}$$

Where Z_0 is characteruistic impedance of microstrip line feeding (50 ohms)

VSWR can be calculated as

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

VSWR v Frequency is plotted in Fig. 4 taking 2 as a reference to measure the bandwidth. Comparison of the suggested antenna is made with some of the antennas in Table 1 with respect to size. It can be seen that the proposed antenna is compact in size and reasonably better gain compared to the other antennas.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

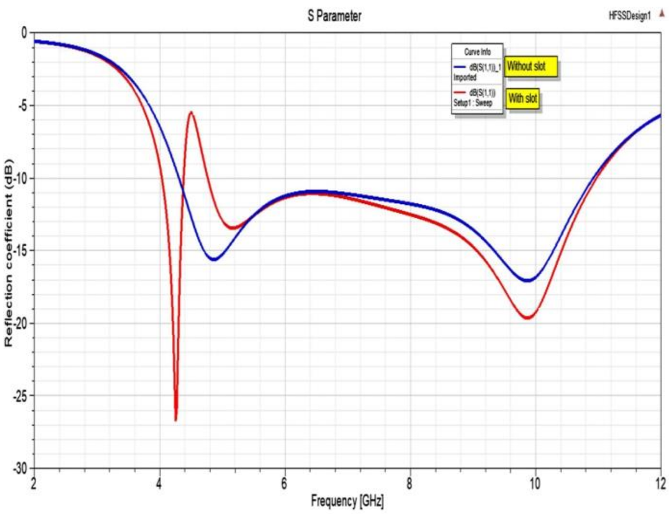

Fig. 3. Reflection coefficient vs Frequency graph

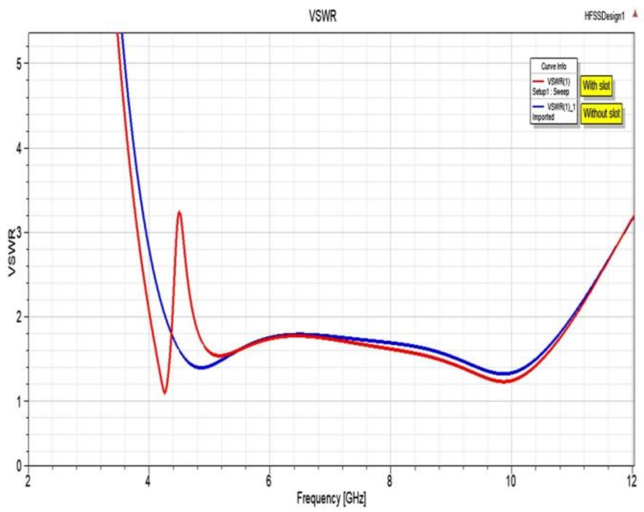

Fig. 4. VSWR vs Frequency graph

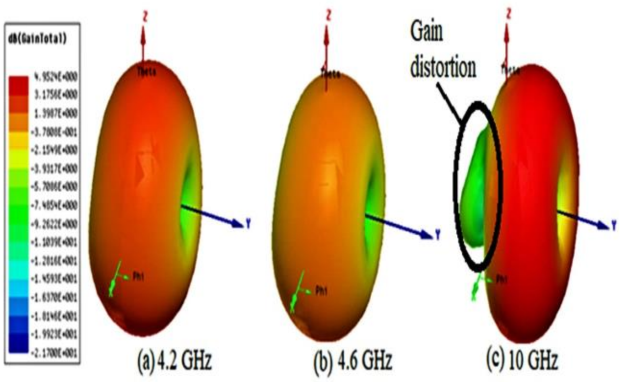

Fig. 5. Gain total at different frequencies in dB

Gain total (dB) for lower frequency (4.2 GHz), notch frequency (4.6 GHz) and higher frequency (10 GHz) is shown in Fig. 5 and the maximum gain is 4.95 dB at 10 GHz. Though the gain is maximum at 10 GHz, we can observe gain distortion as indicated by black circle. Patterns of radiation for E and H planes having bidirectional properties are shown in Fig. 6.

Table 1. Comparison of the suggested antenna with some of the reference antennas

Ref	Size (mm^3)	Frequency Range (GHz)	Notch Frequency (GHz)	Max gain (dB)
[7]	30.3 × 24.8 × 0.8	3.1 -13	5.1-5.7 7.2-7.8	6
[8]	11 × 15 × 1	5-15	6.7-7.1	4
[9]	30 × 36 ×0.4	2.8-13.95	4.85-6.04	4
This work	12 × 20 × 1.6	4-11	4.4-4.8	4.95

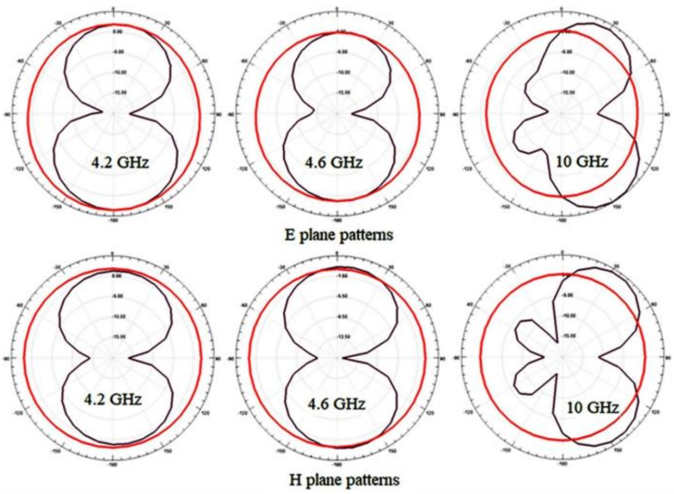

Fig. 6. Radiation patterns (E and H planes) at different frequencies

IV. CONCLUSION

An antenna consists of stepped rectangular patch etched with U shaped slot for UWB applications having stop band for INSAT reception is offered. The antenna helpful to get UWB range of frequencies from 4 to 11 GHz with stop band from 4.4 to 4.8 GHz. The gain is maximum of 4.95 dB at 10 GHz and the radiation patterns are bidirectional.

REFERENCES

1. Garg, R., Bahl, I.J., Bhartia, P. & Ittipiboon, A. Microstrip antenna design hand book. Dedham, MA: Artech House, 2000.
2. Singh, B. & Singh, N., “Design of a corner cut rectangular microstrip antenna having T- slot for Wi-fi, radar and satellite applications”, International Journal of Advanced Research in Computer Science and Software Engineering, vol. 3, no. 2, pp. 1287-1291, 2013.
3. Keshri, P.K., Kaur, R. & Yadav, D.P., “Effect of notch/slot in the radiating patch of a planar antenna configuration”, Indian Journal of Science and Technology, vol. 9, no. 47, pp. 1-7, 2016.
4. Sudhakar, A., Satyanarayana, M., Sunil Prakash, M. & Sharma, S. K., “Compact UWB planar antenna with WLAN band rejection”, International Journal of Microwave and Optical Technology, vol. 11, no. 2, pp. 123-130, 2016.
5. Sekhararao, K.Ch., Babu, Ch., “Design of C-shape slot microstrip patch antenna with line feed for WLAN technology”, IOSR Journal of Electronics and Communication Engineering, vol. 11, no. 6, pp. 72-78, 2016.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

6. Ahmed, Z., Ahmed, M.M., & Ihsan, M.B., "A novel differential fed high gain patch antenna using Resonant Slot Loading", *Radio Engineering*, vol. 27, no. 3, pp. 662-670, 2018.
7. Oraizi, H. & Shahmirzadi, N.V., "Frequency- and time-domain analysis of a novel UWB reconfigurable microstrip slot antenna with switchable notched bands", *IET Microwaves, Antennas & Propagation*,vol. 11, no. 8, pp. 1127–1132, 2017.
8. Ellis, M. S., Zhao, Z., Wu, J., Nie, Z., & Liu, Q. H., "A novel miniature band-notched wing-shaped monopole ultrawideband antenna", *IEEE Antennas and Wireless Propagation Letters*, vol. 12, pp. 1614–1617, 2013.
9. Yoon, C., Lee, W.-J. , Kim, W.-S., Lee, H.-C, Park, H.-D., "Compact band-notched ultrawideband printed antenna using inverted L-slit", *Microwave and Optical Technology Letters*, 54 (1), pp. 143–144, 2012.
10. Balanis, C. A. Microstrip antennas. In *Antenna Theory: Analysis and Design* (pp. 811-820). Wiley-Interscience, 2005.

AUTHORS PROFILE

Dr. A. SUDHAKAR received Ph.D. from Jaipur National University, Jaipur in the year 2016. Presently he is working as an Associate Professor in ECE Department at GMR Institute of Technology, Rajam. He has published/presented 15 papers in National and International Journals/Conferences. His main research interest includes antennas and Wireless Communications

Dr. T. PRABHAKAR received Ph.D. from Anna University, College of Engineering, Guindy, Chennai in the year 2017. Presently he is working as an Associate Professor in ECE Department at GMR Institute of Technology; Rajam. His area of interest is Image processing, Signal processing and Antennas. He has published/presented 25 papers in National and International Journals/Conferences.

.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)