STAIRCASE SLOTTED MICROSTRIPANTENNA RESONATING AT S, C AND X BANDS

P. ChayaDevi, D. Bhargav, K. Kokila, A.S. Jatin Sairam Gona & A. Priyanka
Department of ECE, ANITS, Visakhapatnam, India.

Received: August 25, 2018 Accepted: October 15, 2018

ABSTRACT *As the technology is being updated faster than sooner; the bulky machinery used in various applications is being replaced by compact devices which are handy in the development of the communication systems as they would be delivering high performance over a wide spectrum of frequencies. The advantages of using the compact devices in communication systems are its low cost, minimal weight and low-profile antennas. This technological trend has focused much effort into the design of a Microstrip patch antenna but designing such antenna requires high precision and accuracy for a specific application. This ideology presents the optimized technique used to design these antennas. The Staircase Slotted Micro-strip Antenna is an optimized technique which is used in the S, C and X band applications. The HFSS would be used for the verification for the various antenna parameters to see whether the optimized structure is worth practical implementation.The main motto of this work is to represent the miniaturization by introducing staircase shape at each edge of this patch antenna which operates in S band (2-4 GHz), C band (4-8 GHz) and X band (8-12 GHz). The proposed antenna operates at 2.44 GHz, 5.53 GHz, 7.79GHz and 9.39 GHz with upto 37% size reduction compared to basic patch antenna. The design frequency for the proposed antenna is 2.4 GHz which supports multiband behavior.*

Keywords: *High Frequency Structure Simulator (HFSS); Voltage Standing Wave Ratio (VSWR); Micro-Strip Patch Antenna (MPA); Micro-strip Antenna (MSA)*

I. Introduction

The Microstrip line consists of pattern on one side of the dielectric substrate and ground plane on the other side of it. The Microstrip patch antenna has radiating patch on one side and ground on the other.Thick size dielectric material with lower dielectric constant will provide good antenna performance. It provides better efficiency and better radiation and large operating bandwidth. Microstrip antennas are smaller in size and operate at microwave frequencies.Microstrip patch antenna consists of a conducting patch of any planar geometry on one side of a dielectric substrate backed by a ground plane on the other side. There are virtually an unlimited number of patch patterns for which the radiation characteristics may be calculated [15].Microstrip patch
antennas (MPA) are called low profile antenna because these can be flush mounted on curved surface and they only require space for the feed line [13].

For many practical designs, the advantages of MSA far outweigh their disadvantages. With continuous research and development, the Microstrip antennas have been applied in many different and successful applications. Nowadays it is the most popular antenna in the wireless communication market.We can find applications of MSA in many various fields of high-tech technology which includes Satellite and Mobile communication, Missile telemetry, biomedical radiator and Radar systems. Microstrip antennas are popular at frequencies above 100 MHz [1].

II. Design technique

The Fig.1 is 'Staircase Slotted Micro-strip Antenna' which has been named based on the staircase shape on the corners of a basic rectangle shaped patch. In order to design this 'Staircase Slotted Micro-strip Antenna' a basic rectangular patch of the same dimensions as that of the Staircase Slotted Micro-strip Antennais to be created and it must be cut using the polyline structure. A Microstrip patch is generally of cooper placed on the top of the dielectric substrate. Ground plane is at Rogers the bottom side of the dielectric substrate [2] [3].

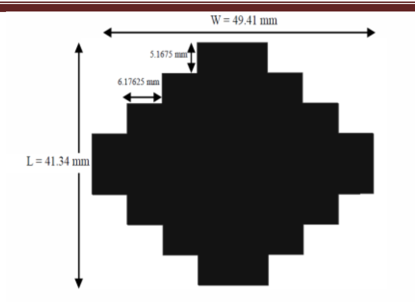


Fig.1: Staircase Slotted Microstrip Antenna

Frequency, thickness and material of the substrate are three necessary parameters for designing the MPA. The Rogers RT/Duroid5880 with relative permittivity 2.2 and height 1.6 mm is used as a substrate material for design of the proposed antenna. Transmission line model is applied to calculate the dimensions of the proposed antenna. Coaxial probe feeding is used to feed the proposed antenna as this type of feed provides better impedance matching to source varying the feed position. The results of the proposed antenna are obtained in terms of Return Loss, Voltage Standing Wave Ratio (VSWR), Gain and Radiation Pattern which have acceptable values of return loss less than -10dB, VSWR less than 2 at each resonant frequency and Gain more than 3dB.The 2.54GHz frequency which is used to design the antenna comes under the ISM band.ISM stands for 'Industrial Scientific Medical'. ISM band are generally open frequency bands, which vary according to different regions and permits. The 2.54 GHz ISM band is a commonly accepted band for worldwide operations [14]. ISM refers to a group of radio bands or parts of the radio spectrum that are internationally reserved for the use of radio frequencies intended for ISM requirements rather than for communication. The equipments which make use of these ISM bands are microwave ovens, cordless phones, military radars and industrial heaters. ISM bands are also called as the unlicensed bands.
The use of ISM equipment generates EM interference that interrupts radio communications that makes use of the same frequency. Therefore, this equipment was restricted to specific frequency bands. Generally, the communication equipment that operates in these bands should tolerate the interference created by the ISM equipment and therefore users don't have any regulatory protection from the use of ISM equipment. In spite of the real purpose of ISM bands, there has been rapid growth in its low power, short range communications. Platforms likeRFID, WLAN Bluetooth devices, Wi-Fi computer network and NFC devices [6] [7].
The Rogers dielectric material with relative permittivity 2.2, height 1.6 mm is taken as substrate material. Coaxial probe feed is employed to feed the proposed antenna in which the inner conductor is soldered to the patch and the outer conductor is soldered to the ground plane. There are basically two different methods to improve the bandwidth one of it is by increasing the width of the substrate and the other is by implementing a slotted patch. The second technique (slotted patch) increases the bandwidth more than the first method, reduces the size of the patch and also shifts the fundamental resonant frequencies to lower side [8]. Coaxial probe feed has low spurious radiation and easy to fabricate [9] Dimensions of proposed antenna are calculated by as follows:

With respect to [Eq (1)] the Width of the patch canbe calculated

$$w = \frac{1}{2f_r} * \frac{c}{\sqrt{\frac{\epsilon_{r+1}}{2}}}. \qquad (1)$$

From [Eq (2)]theϵ_{reff} of the patchcan be expressed as

$$\epsilon_{reff} = \frac{\epsilon_{r+1}}{2} + \frac{\epsilon_{r-1}}{2} * \frac{1}{\sqrt{\left[1 + 12\frac{h}{w}\right]}} \qquad (2)$$

From [Eq (2)] the L_{reff} of the patchcan be expressed as

$$L_{eff} = \frac{c}{2f_r\sqrt{\epsilon_{reff}}} \qquad (3)$$

Using [Eq (4)] ΔL is calculated

$$\Delta L = 0.412h\left[\frac{(\epsilon_{reff} + 0.3)X(\frac{w}{h} + 0.264}{(\epsilon_{reff} - 0.258)X\left(\frac{w}{h} + 0.8\right)}\right] \quad (4)$$

Tocalculate the length of the patch we use [Eq (5)]

$$L = L_{eff} - 2\Delta L. \quad (5)$$

Dimensions of the Ground Plane:

The transmission line model can be applied to infinite ground plane only, but infinite ground plane is not possible for practical use. So, the dimensions of the ground plane are calculated by the following formulas:

$$L_g = 6h + L. \quad (6)$$
$$w_g = 6h + W. \quad (7)$$

Using Eq [1-5] all the antenna design dimensions are obtained and the details are given in the table.1

Antennaparameters	Size
Width of patch(W)	49.41mm
Effective dielectric constant($\in_{eff}$)	2.11
Extension of length(Δl)	0.84mm
Length of the patch(L)	41.35mm
Ground plane width(Wg)	59.01mm
Ground plane length(Lg)	50.95mm

Table 1. design parameters of the antenna which are calculated by using the above equations

III. Mathematical proof for size reduction

The area of the rectangular patch for the given Fig.2 is calculated as follows

Area=length X Width

= (49 X10^{-3}) X (41.34 X 10^{-3})=0.002042 m^2

The above value is 100%

For 10%= 0.0002
20%=0.0004
30%=0.0006
35%=0.0007 and
1%= 0.00002
2%=0.00004
35%+2%= 37%=0.00074

The area of the staircase slotted patch antenna is calculated as follows
Patch:

15.5025 * 6.17625=0.000095 ----------1
10.3350 * 6.17625=0.000060 ----------2
5.16750 * 6.17625=0.000030 ----------3

So, for one sidewe need to add the above three terms i.e. 1+2+3= > 0.000185

So, for 4 – sides
0.000185*4=0.00074

Thus we could show from the above results that the size of the patch has been reduced by 37%.

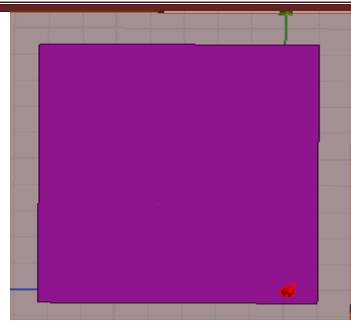
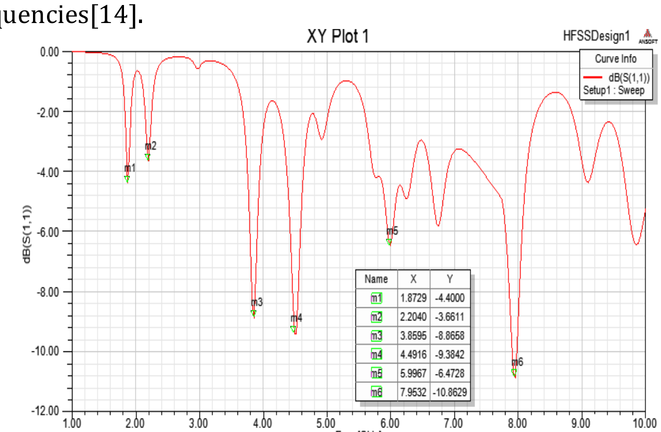


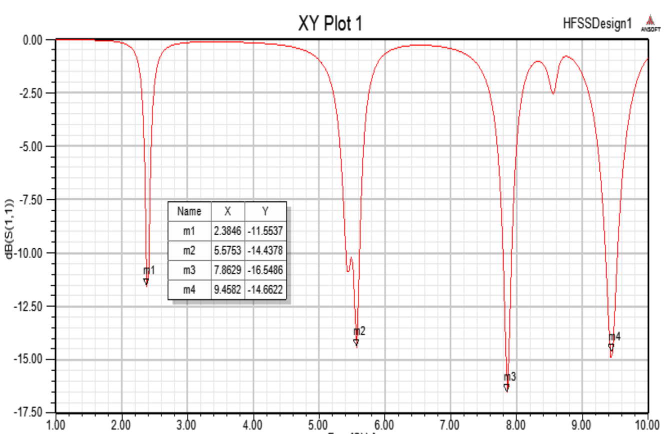
Fig.2 Rectangular patch antenna

IV. Results and Discussions

In Telecommunications, return loss is the loss of power in the signal returned or reflected by a discontinuity in a transmission line or optical fibre. Return loss is a measure of how well the devices or lines are matched.From Fig.3(a) we could say that return loss performance of this rectangular patch antenna has reached a value of greater than -10dB (which is an ideal value) only at one particular frequency which is why the staircase slotted micro-strip antenna Fig.3(b) has been used which obtains the ideal value of return loss at four different frequencies[14].



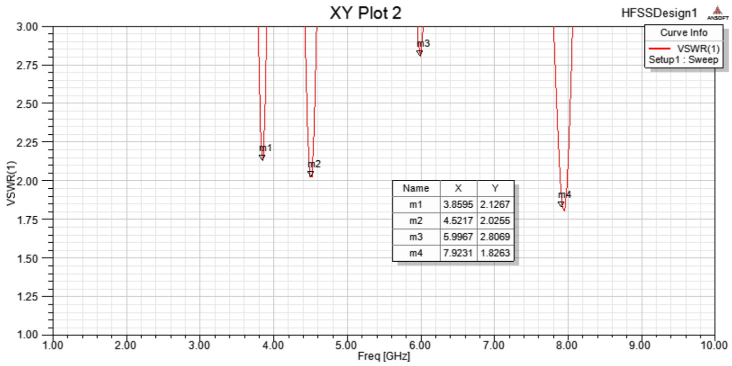
(a)



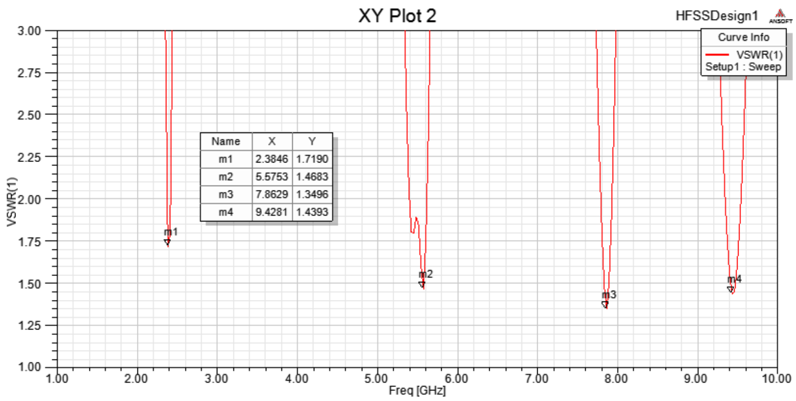
(b)

Fig.3: Comparison of Return loss between the performance of
(a)Rectangular patch antenna, (b) Staircase Slotted Micro-strip Antenna.

The VSWR is an indication of the amount of mismatch between an antenna and the feed line connecting to it. The value of VSWR should be less than 2 for good antenna performance [11].From Fig.4(a) we could say that VSWR performance of this rectangular patch antenna has reached a value of less than 2 (which is an ideal value) only at one particular frequency which is why the staircase slotted micro-strip antenna Fig.4(b) has been used which obtains the ideal value of VSWR at four different frequencies.



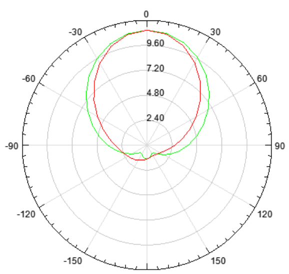
(a)



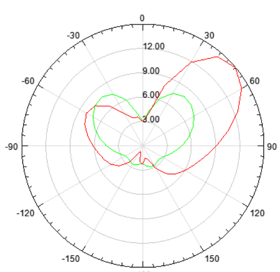
(b)

Fig.4: Comparison of VSWR between the performance of
(a)Rectangular patch antenna, (b) Staircase Slotted Micro-strip Antenna.

The radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antennas far field.The 2D far-field radiation patterns are shown in the Fig.5.
The radiation patterns are obtained at four different frequencies i.e., at 2.44GHz, 5.53GHz, 7.79GHz, 9.93GHz [16].



(a)



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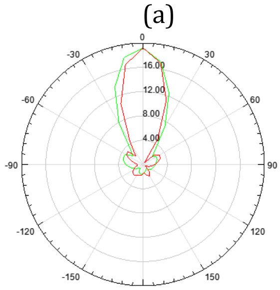
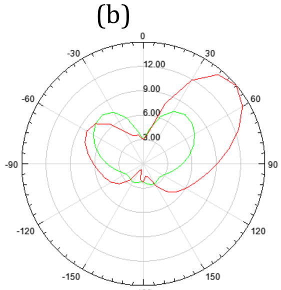


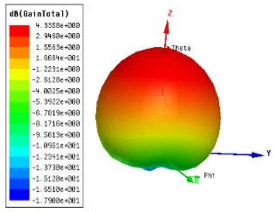
(c)



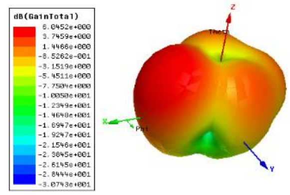
(d)

Fig.5: Radiation pattern at resonant Frequency of (a)2.44GHz, (b) 5.53GHz, (c)7.79GHz, (d)9.93GHz

The ratio of power required at the input of a loss-free reference antenna to the power supplied to the input of the given antenna to produce in a given direction. The Gain(G) of the proposed antenna are shown in Fig.6



(a)



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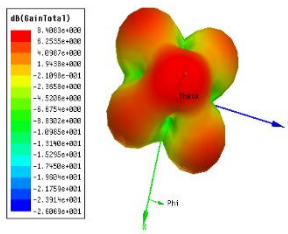
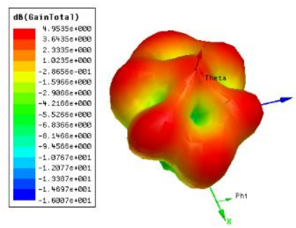


(c)



(d)

Fig.6: Antenna Gain at resonantFrequency of (a)2.44GHz, (b) 5.53GHz, (c)7.79GHz, (d)9.93GHz

Parameters	Values Obtained at different frequencies			
	2.4 GHz	5.5 GHz	7.79GHz	9.3GHz
Return loss	-11.5	-14.3	-16.54	-14.88
VSWR	1.71	1.46	1.34	1.43
Bandwidth	49MHz	280MHz	220MHz	756MHz
Gain	4.3358	6.0452	8.4083	4.937

Table 2. Obtained parameters at different frequencies

V. Conclusion

The proposed antenna is designed at frequency 2.4 GHz and fed by the coaxial probe feed. The results in Table 2. show that the feed position is accurate because there is good impedance matching between the feed and the antenna. The proposed antenna operates in triple band S, C and X band of frequencies. Patch size reduction of 37% is achieved without affecting the performance of the antenna. The proposed antennas have achieved good impedance matching, stable radiation patterns and high gain.

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