Slotted Microstrip Patch Antenna: A Way to Improve the Performance of Microstrip Patch Antenna

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Abstract— Now a days, In wireless communication the most challenging task is to design antennas with light weight , low cost and better performance. Microstrip antennas are widely used antennas because of it's several advantages like compact size, low cost and easy to fabricate. But Microstrip antennas have also several limitations of low gain and low bandwidth. This paper describes the performance improvement technique of Microstrip antennas, which contains design rule of radiating patch, proper feed position and loading slot on patch .

.***Keywords***- *Slotted patch antenna, coaxial feed, Return loss, Bandwidth, VSWR*

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I. Introduction

In today's wireless communication , the most important requirement is of antenna with low profile. Most probably for the handheld devices, the challenging task is to design antenna which provide improved performance day by day with miniaturized size. The most probably preffered and extensively used antennas are Microstrip antennas because of easy to integrate with circuits.

Microstrip antenna consist of patch which is very thin metallic strip or sheet placed above ground plane separated by a substrate of dielectric material. The performance of the microstrip antennas depends on the height of the substrate and dielectric constant of substrate. The performance of microstrip antennas are good for thick substrate with lower dielectric constant of substrate material. The major limitation of Microstrip antenna is impedance bandwidth is lower for thin substrate. But for the handheld devices and wireless communication , the antenna size should be small and for that the height of substrate should be as small as possible. We have reviewed design rules for microstrip antennas and performance improvement technique with thin substrate, which are discussed in this paper.

This paper mainly contains the sections in which design equations of conventional rectangular radiating patch, proper coaxial feed position, technique to improve performance of antenna with loading slot on radiating patch and theoretical calculation of Return loss and VSWR are described.

II. Design rule of microstrip antenna

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Microstrip antennas consist of patch which is a sheet or thin metallic strip placed on a substrate of dielectric material. The shape of the patch may be rectangular, triangular, circular ,square or of any type. The dielectric constant of material should be in between 2.2 to 12 for antenna designing[3]. The height of the substrate, $h \ll \lambda_0$ [3] (whrere, λ_0= operating wavelength). The designing parameters of microstrip patch antennas for rectangular patch are length of patch(L) and width of patch(W). These two parameters are depends on the height of substrate, dielectric constant of material and resonant frequency(Resonant frequency should be same as operating frequency). The design equations of patch are described in (A) and feed position in (B).

A. *Design equations of patch*

In the Microstrip antennas, the patch is main radiating element. For rectangular patch, the width of the patch(W) is depends on the resonant frequency(f_r) and dielectric constant(ε_r) of the material, which is given by[3],

$$W = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

The effective dielectric constant is introduce to account for fringing effect because some of the waves travel in the substrate and some of in the air.

For $W/h > 1$, the effective dielectric constant is[3],

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \tag{2}$$

The electrical length of patch is greater than the physical length because of fringing effect. If extended dimension of the patch length is ΔL , then

$$\frac{\Delta L}{h} = 0.412 \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \tag{3}$$

Thus the actual length of patch is,

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \quad (4)$$

B. Coaxial Feed position

There are four most popular methods to feed the patch of Microstrip Antennas. In coaxial feed, the outermost conductor is connected to the ground plane and inner conductor is connected to radiating patch. The feed point should be at proper position so that impedance matches between the transmission line and the port.

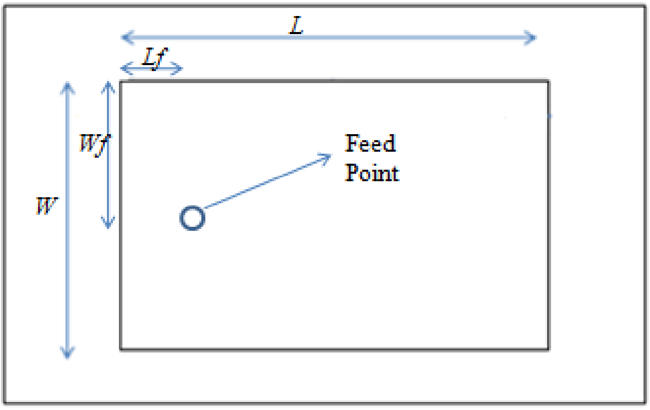


Figure 1. Conventional patch antenna with coaxial feed position

The design rules for patch are same for all four methods only feeding techniques are different. If feed location is (L_f,W_f) [13] then,

$$L_f = \frac{L}{2\sqrt{\varepsilon_{reff}}}$$

$$W_f = \frac{W}{2} \quad (5)$$

Where ,

L_f = position of feed along length of patch
W_f = position of feed along width of patch

III. Slot Loaded Patch Antenna

In the conventional Microstrip antenna, the rectangular slot is loaded on the radiating patch as shown in figure2, of length Ls and width a. It is also necessary to load the slot on patch with proper dimensions such that it can improve the performance of antenna the antenna compared to the performance of conventional antenna. In this section, the slotted Microstrip patch antenna is analyzed. The slot on patch can be analyzed by using duality relationship between the dipole and the slot[2].

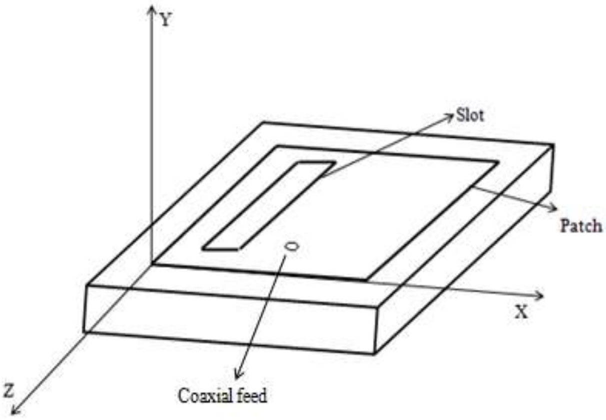


Figure 2. Slot loaded rectangular Microstrip patch antenna

The slot loaded on the patch affect to the performance parameter of the antenna. The slot loaded rectangular microstrip patch antenna can be considered as parallel combination of capacitance C_1, inductance L_1 and resistance R_1 of patch and capacitive reactance of slot[2].

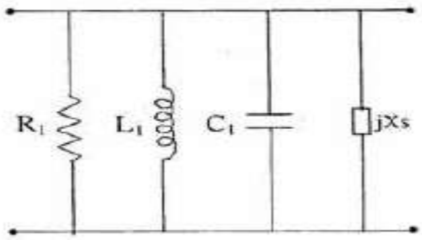


Figure 3. Equivalent circuit of slot loaded on patch

$$C_1 = \frac{\varepsilon_{eff}\varepsilon_0 LW}{2h}\cos^{-2}\left(\frac{\pi z_0}{L}\right) \quad (6)$$

$$L_1 = \frac{1}{C_1\omega_r^2} \quad (7)$$

$$R_1 = \frac{Q}{\omega_r C_1} \quad (8)$$

h = Thickness of substrate
ε_{eff} = Effective dielectric constant
ε_0 = Permittivity of free space
z_0 = Feed point location along z-axis

The input impedance (Z_{in}) of the above excluding slot can be expressed as,

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

Then above expression can be expressed as,

$$Z_{in} = R - jX \quad (9)$$

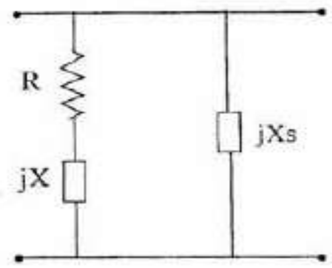


Figure 4. Modified Equivalent circuit of slot loaded on patch

The input impedance of slot loaded on patch can be calculated using above Figure 4 as,

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

Reflection coefficient, $\Gamma = \frac{Z_0 - Z_{ins}}{Z_0 + Z_{ins}}$

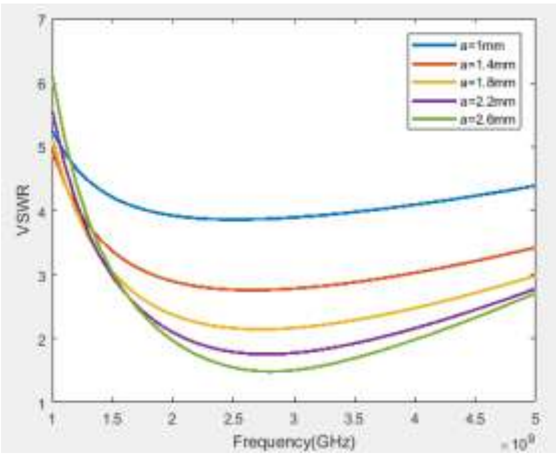
Return Loss $= 20\log|\Gamma|$ (10)

$$\text{VSWR} = \frac{1+|\Gamma|}{1-|\Gamma|} \quad (11)$$

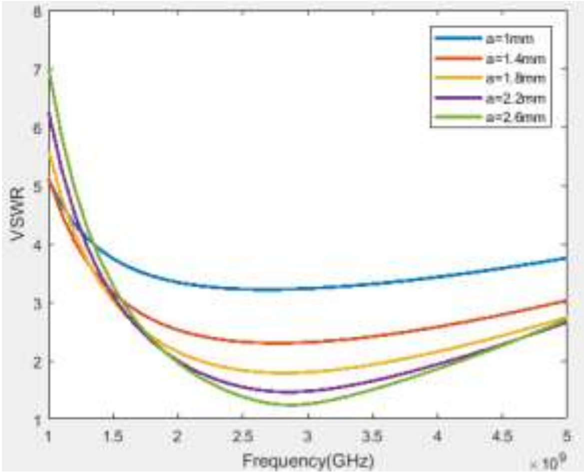
Thus return loss and VSWR affect by the slot on patch. Bandwidth is depend on the return loss and VSWR plot. So bandwidth also affect by the slot on patch.

IV. Theoretical Calculations

The slotted Microstrip antenna is analyzed in above section and in this section the value of Return loss and VSWR are calculated theoretically using equations described in (III) for different slot widths and slot lengths. The patch was designed for frequency 3.0GHz , dielectric material of substrate RT Duriod (ε_r=2.2) and thickness of substrate is 0.0159λ.



(i)



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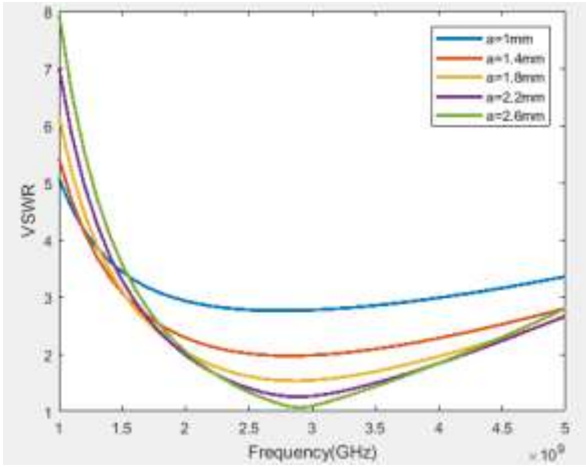

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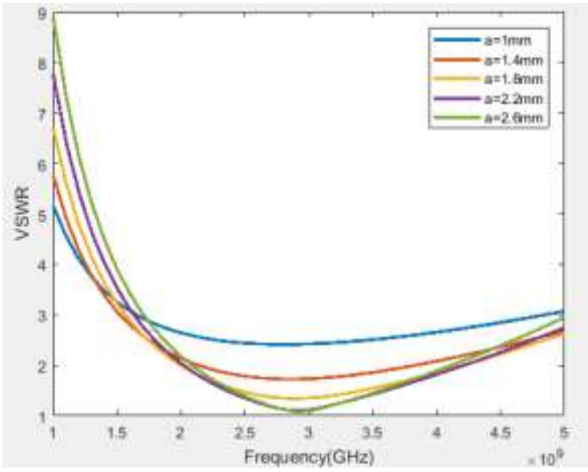
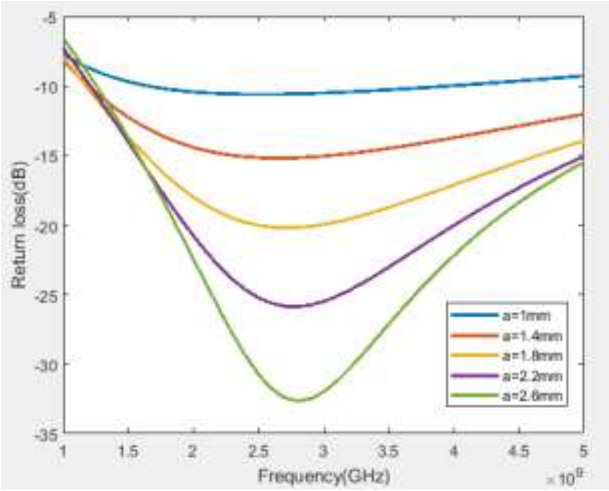


(iv)

Figure 5. variation in VSWR Vs frequency in GHz for different slot width(a) for given slot length(L_s); (i) L_s=10mm, (ii) L_s=12mm, (iii) L_s=14mm, (iv) L_s=16mm



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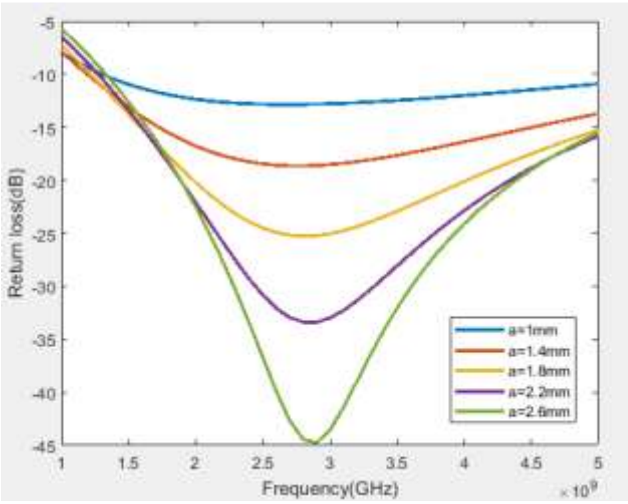

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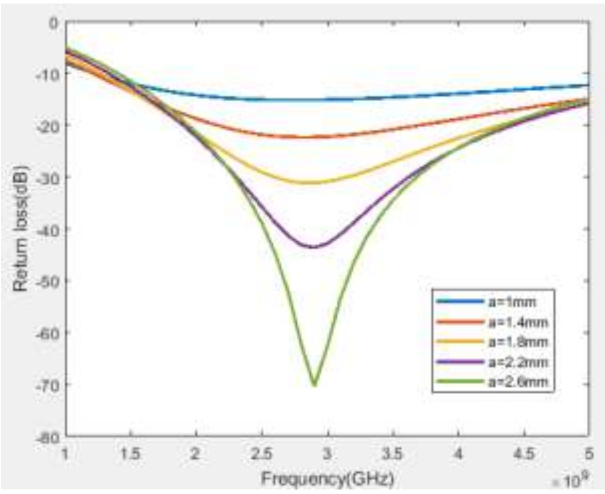

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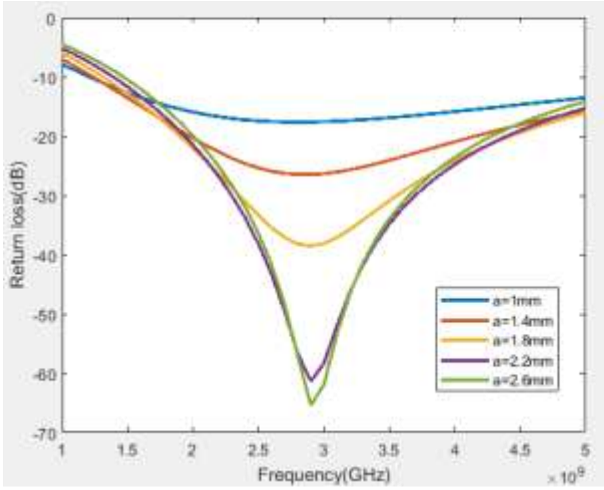

(iv)

Figure 6. variation in return loss Vs frequency in GHz for different slot width(a) for given slot length(L_s); (i) L_s=10mm, (ii) L_s=12mm, (iii) L_s=14mm, (iv) L_s=16mm

From the Figure 5 and 6, it can be observed that resonance frequency decreases with increasing slot width for same slot length. The bandwidth or frequency variation is more for lowest slot length with same slot width. The value of VSWR and return loss also decreases as slot width increases.

V. CONCLUSION

By loading the slot, resonant frequency can be decreases and performance parameter values also improve. Resonant frequency varies slightly for different slot width as compared patch without slot. The bandwidth is also increases with slot width for given slot length.

REFERENCES

[1] M.A.Matin, A. I. Sayeed, "A Design Rule for Inset-fed Rectangular Microstrip Patch Antenna", WSEAS Transactions on Communications ,vol. 9, pp. 63-72, January 2010.

[2] Shivnarayan, Shashank Sharma, Babau R Vishvkarma, "Analysis of slot loaded microstrip patch antenna", Indian Journal of Radio and space Physics, vol. 34, pp. 424-430, December 2005.

[3] C.A.Balanis, "Antenna Theory , Analysis and Design ", 3rd ed.

[4] Muhammad Umar Khan, Mohammad Said Sharawi, Raj Mittra, "Microstrip patch antenna minituarization techniques: a review", IET Microwaves, Antennas & Propagation, vol. 9, pp. 913-922, 2015.

[5] Ranjan Mishra, Raj Gaurav Mishra, Piyush Kuchhal, "Analytical Study on the Effect of Dimension and Position of Slot for the Designing of Ultra Wide Band (UWB) Microstrip Antenna", Intl. Conference on Advances in Computing, Communications and Informatics (ICACCI), pp. 488-493, September 2016.

[6] Ulas Keskin, Bora Doken, Mesut Kartal, "Bandwidth improvement in microstrip patch antenna", 8th International Conference on Recent Advances in Space Technologies (RAST), IEEE Conference, pp. 215-219,June 2017.

[7] Girish Kumar, K.P.Ray, "Broadband Microstrip Antennas", Artech House.

[8] Dinesh Yadav,“L- Slotted Rectangular Microstrip Patch Antenna”,2011 International Conference on Communication Systems and Network Technologies, IEEE Conference, pp.220-223, June 2011.

[9] Kin-Lu Wong, “Compact and Broadband Microstrip Antennas”, A Wiley Interscience Publications.

[10] Mohamed Mamdouh M. Ali, Osama Haraz, Saleh Alshebeili, Abdel-Razik Sebak, "Broadband printed slot antenna for the fifth generation (5G) mobile and wireless communications”,2016 17th International Symposium on Antenna Technology and Applied Electromagnetics (ANTEM) , July 2016.

[11] Alak Majumder, “Rectangular Microstrip Patch Antenna Using Coaxial Probe Feeding Technique to Operate in S-Band”, International Journal of Engineering Trends and Technology (IJETT),vol. 4,pp. 1206-1210,April 2013

[12] Wonbin Hong, Kwang-Hyun Baek, Seungtae Ko, “Millimeter-Wave 5G Antennas for Smartphones: Overview and Experimental Demonstration”, IEEE Transactions on Antennas and Propagation, vol. 65, pp. 6250 – 6261.

[13] S. E Jasim, M. A. Jusoh, M. H. Mazwir and S. N. S. Mahmud, “Finding the best Feeding point location of patch antenna using HFSS”, ARPN Journal of Engineering and Applied Sciences, vol. 10, pp. 17444-17449, December 2015.