Analysis of Extremely Low VSWR Characteristics of Feed Network of Rectangular Microstrip Patch Antenna

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Abstract— **This paper describes extremely low VSWR characteristics of coaxial and microstrip feed networks for slot-loaded rectangular microstrip patch antennas. Both Inset feed and coaxial feed from the ground plane are considered to compare results for best impedance matching without much change in radiation pattern. It is found that by choosing feed structures and adjusting the slot dimensions and its number, resonance frequency can be adjusted to a desired value with very low VSWR characteristics. The design is optimized by modeling and simulation using Ansoft HFSS-13 software. Using low loss substrate of thickness 1.6mm having dielectric constant 2.2 design is made at 1.8 GHz which results in VSWR of as low as 1.01 and band width 1.8%.**

Keywords- ***Microstrip patch antenna, Slotted patch antenna, Low VSWR feed.***

I. INTRODUCTION

Modern telecommunication device are required to be small and should be able to integrate several functionalities. A Microstrip antenna is well suited for wireless communication due to its light weight, low volume and low profile planar configuration which can be easily conformed to the host surface. Strip and slot combinations offer an additional degree of freedom in the design of microstrip antennas. Lower VSWR can be achieved by cutting slot. Bandwidth of patch antenna can be increased by various methods such as by increasing the thickness of substrate with low dielectric constant, by cutting slot and by different shape of antenna while input VSWR can be low. The aim of the work is to study the effect of narrow slots on the performance characteristics of rectangular microstrip antenna such as VSWR, Return loss and bandwidth.

Many researchers have reported narrow band rectangular patch antenna characteristics with some improvement in VSWR and bandwidth. Shivnarayan,S. Sharma,R. Vishvakarma[1],V. K. Singh, Z. Ali, Dr. S. Ayub [2] ,P.A. Ambresh, P. M. Hadalgi, P.V.Hunagund[3] and Ashish Kumar [4] , described in their papers , Bandwidth, return loss improvement due to slot. The return loss of a normal patch antenna designed at the resonant frequency of 2GHz has been compared with that of the same patch antenna along with additional slots on the patch antenna and it has been measured that the return loss is improved by 7 dB.

In this paper extremely low VSWR characteristics of coaxial and microstrip feed networks for slot-loaded rectangular microstrip patch antennas are analyzed. Both Inset feed and coaxial feed from the ground plane are considered to compare results for best impedance matching without much change in radiation pattern. It is found that for a given feed structure, adjusting the slot dimensions and its number, the resonance frequency can be altered to a desired value with very low VSWR characteristics. The design is optimized by modeling and simulation using Ansoft HFSS-13 software. Using low loss substrate of thickness 1.6mm having dielectric constant 2.2 design is made at 1.8 GHz which results in VSWR of as low as 1.01 and band width 1.8%.

II. DESIGN EQUATIONS

A rectangular patch is designed with Rogers RT/duroid 5880(tm) substrate material of dielectric constant 2.2 and substrate height h=1.6mm.The designed frequency is selected f=1.8 GHz. The dimensions of the patch are calculated for the excitation of radiating mode TM_{100}[5,6]. Since the patch sides parallel to x axis is non-radiating, the patch width W can be selected without considering the fringing from the following:

$$\text{Patch width } W = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{30}{2f_r(GHz)}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

where f_r is the resonant frequency of the antenna, v_0 is the velocity of the light in free space. Where fringing electric field is important , the effective dielectric constant of the propagation medium needs to be considered as

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1+12\frac{h}{W}]^{-\frac{1}{2}}; \text{ for W/h>1} \qquad (2)$$

Guide wavelength in the propagation medium is

$$\lambda_{eff} = \lambda_0 / \sqrt{\varepsilon_{reff}} \qquad (3)$$

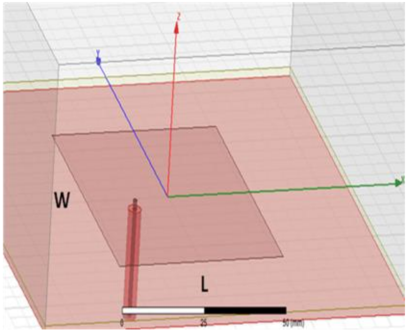
The patch length is selected from the resonant condition and the fringing field consideration and is given by

$$L = \lambda_{eff} / 2 - 2\Delta L \qquad (4)$$

Here the effect of fringing field length subtracted from both sides are given by

$$\frac{\Delta L}{h} = 0.412 \frac{(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)} \qquad (5)$$

where the width is chosen such that W > L. Three basic feed networks are shown in Fig. 1



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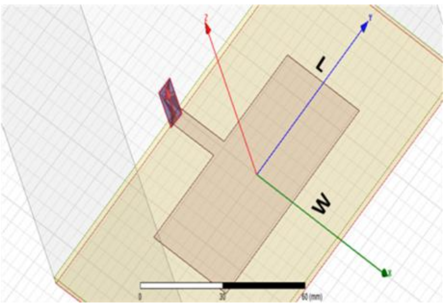

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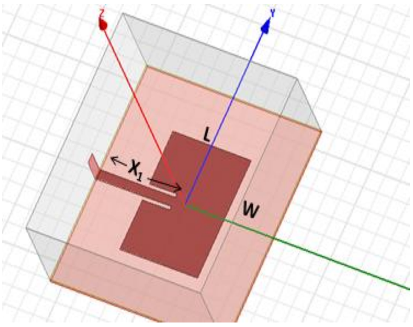

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Figure 1. Coaxial and microstrip feed networks(a. coaxial feed, b. microstrip feed, c. microstrip inset feed)

The input impedance at resonance for the coaxial feed for TM_{100} mode is given by [7]

$$R_{in} = R_r \cos^2\left(\pi \frac{L/2 - x_0}{L}\right); \quad R_r > R_{in} \qquad (6)$$

Here R_r is the radiation resistance at resonance frequency and co-ordinate of the coaxial feed is $(-x_0,0)$. The radiation resistance can be computed

$$R_r = \frac{1}{2G} = \frac{60\pi^2}{\left[-2 + \cos(k_0 W) + k_0 W S_i(k_0 W) + \frac{\sin(k_0 W)}{k_0 W}\right]} \qquad (7)$$

Where $S_i(X) = \int_0^X \frac{\sin(t)}{t} dt$

The input impedance at the feed point of the microstrip feed line is given by [5,6]

$$Z_{in} = \frac{1}{2G} = R_{in}(x = 0) \qquad (8)$$

Where the input conductance is

$$G = \frac{1}{90}\left(\frac{W}{\lambda_0}\right)^2; \quad W < \lambda_0 \qquad (9)$$

For improving the impedance match an inset feed can be used with inset depth x_1 as shown in Fig.1c. and is given by

$$R_{in}\big|_{x=x_1} = \frac{1}{2G_1}\cos^2(\frac{\pi}{L}x_1) = R_{in}\big|_{x=0}\cos^2(\frac{\pi}{L}x_1) \qquad (10)$$

where x_1 is the inset depth.

The operating frequency of the proposed antenna is chosen at 1.8 GHz, which is used for Wi-Fi connectivity. For frequency=1.8GHz, the antenna dimensions are found as W=65.8mm and L=53.5mm. For the coaxial feed matching with 50 ohm feed line occurs for the probe position (-7mm,0) according to equation no. 6. The depth x_1 is adjusted to get good impedance match yielding $R_{in} \approx$ feed line impedance=50Ω when fed at the centre of the patch y=0 and

x_1=17.3mm, for obtaining best return loss. The bandwidth of the antenna is given by

$$\% BW = 100x (f_2 - f_1) / f_r \qquad (11)$$

where, f_1 = the first frequency of the bandwidth
f_2 = the final frequency of the bandwidth
f_r= the resonance frequency

III. SIMULATION AND MODELING ANALYSIS

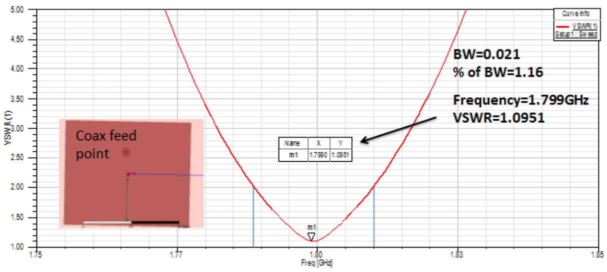
Above formulations were derived based on many assumptions. Therefore the above co-ordinates of feed point could be more accurately determine by using numerical techniques . In this paper the modeling and simulation of the antenna is done using ANSOFT HFSS-13. The optimized value of feed points tabulated in Table no.1 along with VSWR and return loss Vs frequency. It is seen that for co-axial feed position (-11mm,-1mm) produces best results of VSWR 1.09, return loss -26.9dB at 1.799GHz with bandwidth 1.16%. For the inset feed with x_1=19mm, at y=0 , the lowest VSWR is obtained as VSWR=1.015, return loss = -42dB at frequency 1.7850GHz with bandwidth of 1.8%. It is therefore seen that inset feed produces better result than the coaxial feed system.

To improve the performance with co-axial feed, thin rectangular slots (slot width=1mm) are cut parallel to x-axis as shown in Fig.2. The co-axial feed has the advantage of no feed radiation as compare to microstrip feed structure. First, a rectangular micro-strip patch antenna is designed based on standard design procedure to determine the length (L) and width (W) for resonant frequency 1.8GHz.

The narrow parallel slots are cut in multiple numbers with lengths distributed according to the binomial coefficients. The antenna performance of VSWR , return loss and radiation pattern are shown in Figs. 2,3 and 4 respectively. It is seen that 3 and 5 parallel slots yield best result of VSWR 1.09, return loss nearly -27dB and bandwidth 1.44%. It is also observed

TABLE I.

Basic structure and Dimensions L x W	Feed network	Slotted Tuned structure	Operating frequency (GHz)	Absolute VSWR	Return Loss in dB	% Band width at S=2
53.5 x 65.8	Co-axial	without slot	1.799	1.0951	-26.8567	1.16
53.5 x 65.8	Co-axial	2 slots	1.8020	1.0763	-28.6964	1.415
53.5 x 65.8	Co-axial	3 slots	1.8010	1.0892	-27.3892	1.4436
53.5 x 65.8	Co-axial	5 slots	1.8020	1.0987	-26.5625	1.4428
53.5 x 65.8	Co-axial	7 slots	1.8070	1.0843	-27.8637	1.383
53.5 x 65.8	Microstrip	Inset feed	1.7850	1.0150	-42.5444	1.8207



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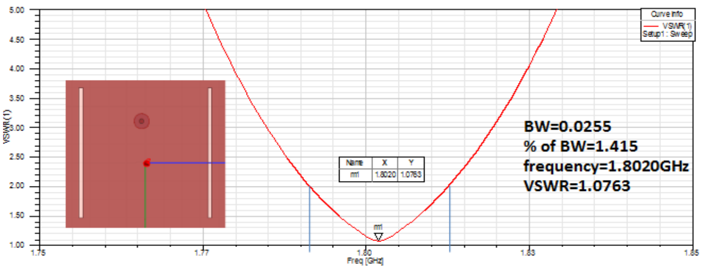

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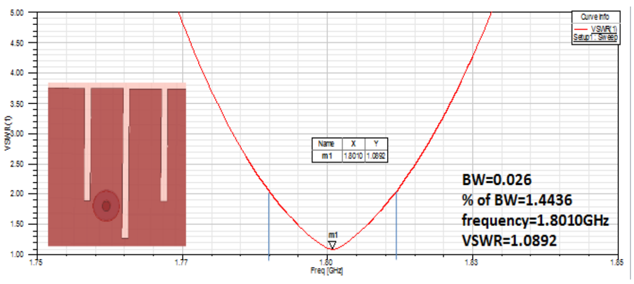

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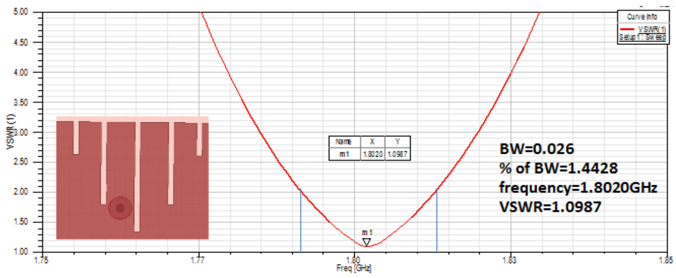

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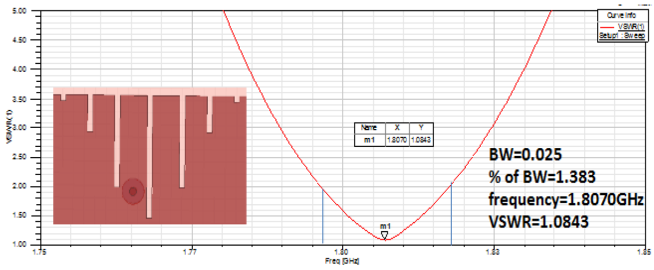

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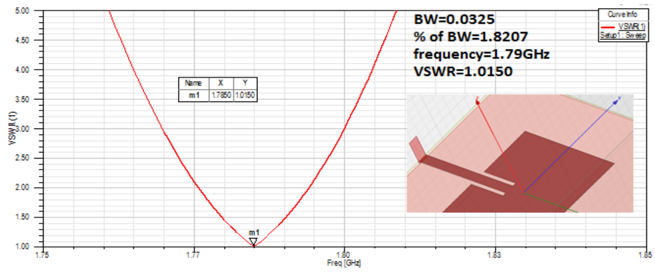

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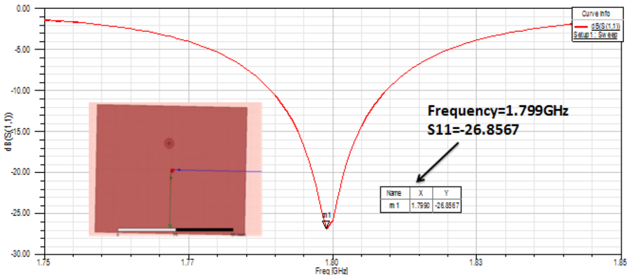
Figure 2. VSWR Vs frequency of rectangular patch antenna (a. with slot coax feed, b. 2 slots with coax feed, c. 3 slots with coax feed, d. 5 slots with coax feed, e. 7 slots with coax feed, f. inset with microstrip feed)



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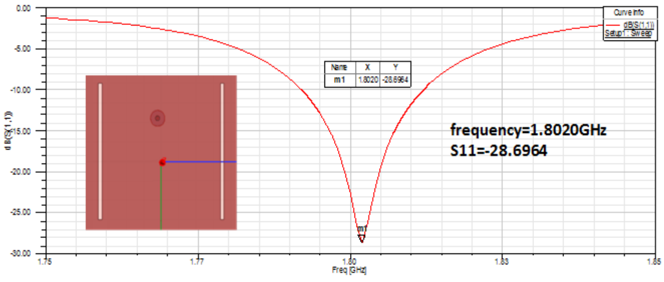

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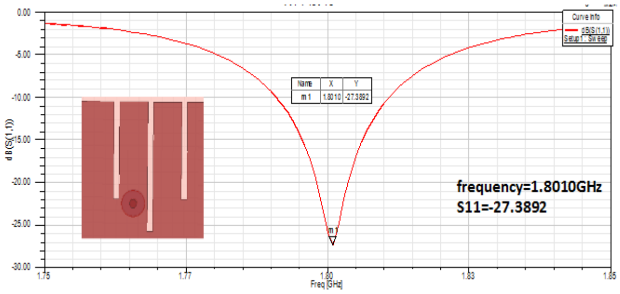

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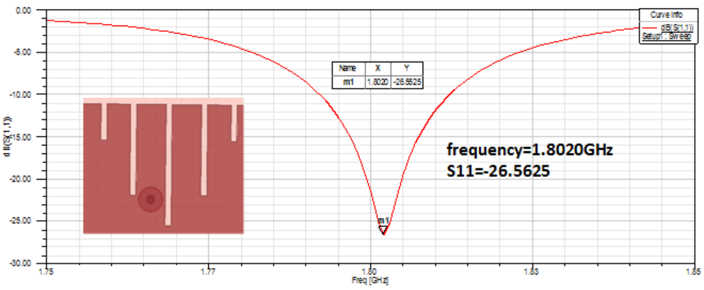

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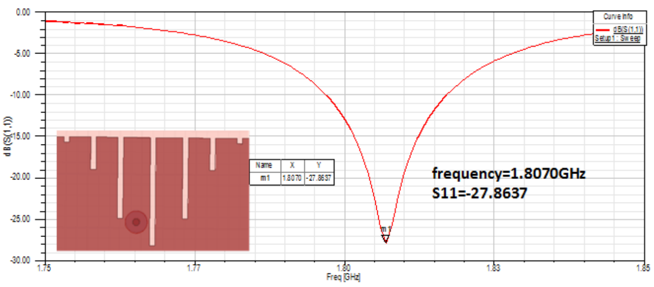

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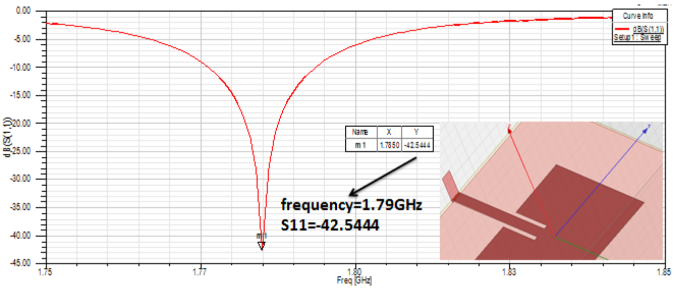

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Figure 3. Return loss Vs Frequency for rectangular microstrip antenna (a. with slot coax feed, b. 2 slots with coax feed, c. 3 slots with coax feed, d. 5 slots with coax feed, e. 7 slots with coax feed, f. inset with microstrip feed)

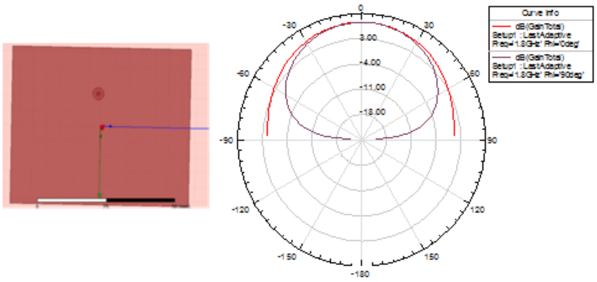

Figure 4. Radiation Pattern for rectangular microstrip antenna

IV CONCLUSION

The analytical formulations presented in the paper produce results, which may not be very accurate due to several assumptions incorporated in the analysis. For more accurate results, simulation and modeling of micro-strip patch antenna are done by using ANSOFT HFSS-13 software, which is based on finite element method. The variation of VSWR and return loss with frequency of rectangular patch antenna with tuning narrow parallel slots shows that the analytical results and the simulation results vary significantly. The simulation and modeling results are more accurate and agree well at the designed frequency.

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