Investigation of Multilayer Probe-Fed Microstrip Antenna for Ultra Wideband Operation

N. Ghassemi[1], M. H. Neshati[1], J. Rashed-Mohassel[2]
1- Electrical Engineering Dept., Sistan & Baluchistan University, Zahedan, Iran.
2- Center of Excellence on Applied Electromagnetic Systems, University of Tehran, Tehran, Iran.

***Abstract-* In this paper a multilayer multi-resonator probe-fed microstrip antenna is numerically investigated using Method of Moments (MoM). The antenna structure includes a feed patch and two parasitic patches located on the bottom layer while another parasitic patch is placed on the top layer and the two layers are separated by an air gap. The effect of feed-point location and distance between parasitic patches with feed patch on the radiation performance of the antenna are investigated. The results show that impedance bandwidth of 7.6 GHz (53.9%) for VSWR<2 and gain of 7.53 dB is obtained.**

I. INTRODUCTION

Microstrip Antennas (MSAs) have been widely used in wireless communication and radar systems in recent years. The advantages of these types of antennas are small size, lightweight, low cost and easy to apply with Microwave Integrated Circuits (MICs). However, MSAs suffer from some disadvantages including narrow bandwidth and low gain. Techniques such as Multilayer, Multiresonator MSAs using low dielectric constant substrate have been reported in literature to improve the impedance bandwidth and also to obtain dual band operation response of MSAs [1-7].

In this paper a multilayer multiresonator MSA consisted of a feed patch and three parasitic patches, for ultra wideband application from 10 GHz to 18 GHz is investigated numerically. The effects of three important factor including: parasitic patches, location of feed point and the distance between different patches on the radiation performance of the antenna are studied. The results show that impedance bandwidth of 53.9% for VSWR<2 is obtained and the simulated gain of the antenna is around 7 dB. This study shows the importance of the different parameters of the antenna which can be used for designing this type of antenna for other frequencies.

II. ANTENNA STRUCTURE

The antenna structure is shown is Fig 1. The feed patch is placed at the centre of the printed circuit (PC) board and is excited by a probe. The size of this patch is derived at the center frequency of 14 GHz (at the middle of the bandwidth) using equations 1 to 4 [2, 4] based on the substrate with ε_r =2.1 with H_1=2.4 mm. The location of the feed probe is calculated by equation 5 [2] for the best impedance matching. Two parasitic patches are placed on the bottom layer of the structure while the distances of these unexcited patches from the feed one is S_1 and S_2 respectively. Another layer is located on top of the first layer. The layers are air gap coupled and the distance between these two layers is fixed to H_2 = 1.6 mm. The third parasitic patch, with the dimension of L_4, is placed at the centre of the top layer. All dimensions of the antenna structure are shown in Table 1.

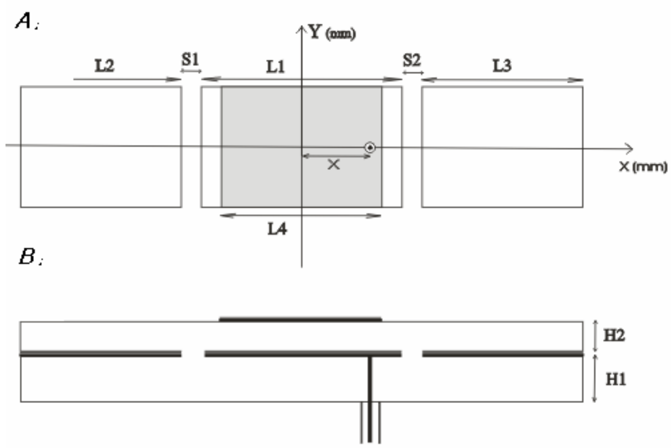


Figure 1: Antenna structure: A: Top view , B: Side view

$$L = \frac{c}{2 f_0 \sqrt{\varepsilon_{re}}} \quad (1)$$

$$\varepsilon_{re}(l) = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} F(\frac{l}{h}) \quad (2)$$

$$F(\frac{a}{h}) = \begin{cases} (1+12\frac{h}{a})^{-\frac{1}{2}} + 0.04(1-\frac{a}{h})^2 & \frac{a}{h} \le 1 \\ (1+12\frac{h}{a})^{-\frac{1}{2}} & \frac{a}{h} \ge 1 \end{cases} \quad (3)$$

$$W = \frac{c}{2 f_0 \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (4)$$

$$X = \frac{L}{2\sqrt{\varepsilon_{re}(l)}} \quad (5)$$

TABLE I

DIMENSIONS OF THE ANTENNA

L_1	L_2=L_3	L_4	W
9 mm	5.2 mm	7.2 mm	4.5 mm

H_1	H_2	ε_{r2}	ε_{r1}
2.4 mm	1.6 mm	1	2.1

III. ANTENNA SIMULATION

The antenna structure is simulated using the Ansoft Designer, which is a software package to calculate *S*-parameters of high frequency structures such as transmission lines and antennas based on Method of Moment (MoM). In general, in Ansoft Designer the surface of the geometric model is automatically divided into a large number of triangle and rectangle elements, and all these elements together are refereed to the mesh. The software solves the Mixed-Potential Integral Equation (MPIE) [8] and calculates current distribution of the surfaces of the mesh. Using surface currents, the electromagnetic radiation (far field) fields of the structure are obtained and different parameters of the antenna including radiation patterns, directivity can be calculated.

For the antenna structure under investigation a parametric study including: the feed patch characteristic, the effect of adding parasitic elements and the effect of feed location are studied in following sections. All numerical results in this paper are based on an infinite ground plane which can be defined as a Metalized Signal Boundary [8].

IV. 1 FEED PATCH CHARACTERISTICS

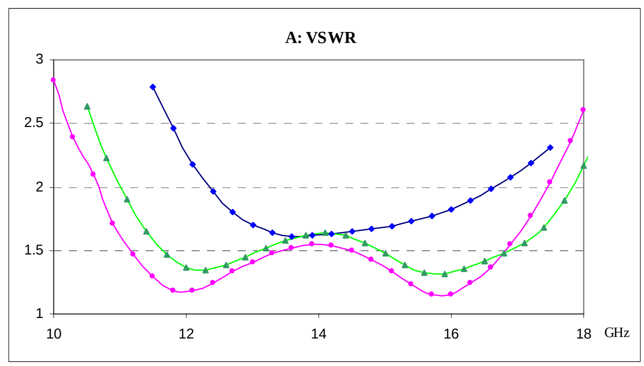
First of all, the feed patch was investigated by the software package. The result for the input impedance is shown in figure 2.A. The width of the feed patch is optimized for the higher bandwidth. In comparison to the theoretical width of 9 mm, it is adjusted to 4.5 mm for the antenna structure. It can be observed that the impedance bandwidth of 4.3GHz (29.7%) is obtained. Also in figure 2.B the antenna gain curve is shown which shows 5.84 dB at the 14 GHz.

V. 2 THE EFFECTS OF BOTTOM LAYER PARASITIC PATCHS

Two parasitic patches were added at the bottom layer. These patches may have different resonant frequencies which depend on their sizes and their distances to the feed patch. Figure 2.A shows the input impedance of the antenna structure while probe feed is located at x = 3 mm and y = 1 mm. It can be observed that for VSWR<2, the bandwidth 6.8 GHz (47.2%) is obtained while the gain of the antenna is increased to 6.94 dB at the frequency of 14 GHz. As a result in comparison to the single patch the antenna bandwidth and gain are improved by 17.5% and 1.1 dB respectively at 14 GHz.

VI. 2 THE EFFECTS OF TOP LAYER PARASITIC PATCH

To improve the radiation characteristics of the antenna another layer with a parasitic patch was added on top of the first layer and the whole structure is simulated by Ansoft Designer. Feed location is kept at x = 3 mm and y = 1 mm and the distance between parasitic patches at bottom layer is fixed to S_1=S_2= 1 mm in simulation. The numerical results of the input impedance and the gain of the antenna is shown in figures 2.A and 2.B respectively. In comparison with the previous results, it can be seen that the bandwidth of 6.9 GHz (49.3%) and 7.36 dB gain at the frequency of 14 GHz is obtained. Moreover, it can be observed that in comparison to the single layer structure better matching is obtained in the whole bandwidth and the gain of the antenna is improved especially at higher frequencies.



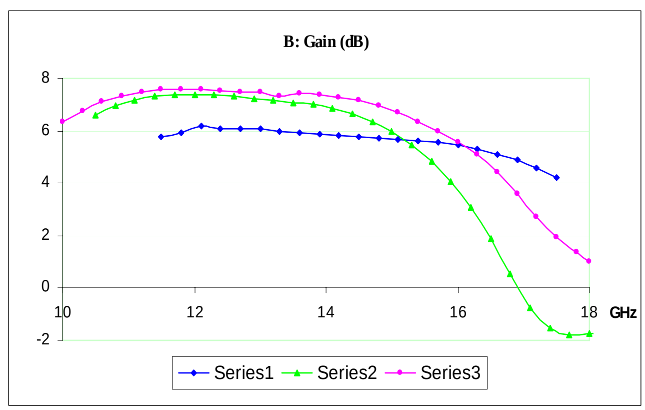


Figure 2. A: VSWR B: Gain of the antenna. Plot 1 is for center feed patch without other patches, plot 2 is for 3 patches in bottom layer and plot 3 is for 3 patches in bottom layer and a patch on the top layer.

VII. THE EFFECTS OF FEED POINT LOCATION

The feed point location has a significant effect on the impedance bandwidth of the antenna. To investigate this effect, the simulation results for eight different feed point locations from the center of the patch are summarized in

Table 2. The definition of the parameters F_1, F_2 and, Y are shown in figure 3. It can be seen at the location of x = 3 mm and y = 1.5 mm the obtained bandwidth is maximum while the maximum gain is 7.52 dB. It is clear from Table 2 and figure 3 that the point x = 3 and y = 1.5 is a good choice for the feed probe. Moreover, our investigation shows that feed location has not a significant effect on the radiation pattern of the antenna.

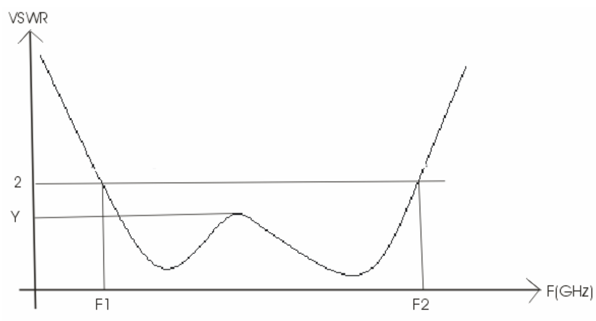


Figure 3. Parametric plot of VSWR

TABLE II

EFFECT OF FEED POINT LOCATION

X,Y	F1	F2	BW(GHz)	Maximum gain(dB)
2.5, 0	10.3	16.2	5.9	7.1
3, 0	11.1	16.4	5.3	7.34
3.5, 0	11.7	16.3	4.6	7.67
3.5, 0.5	11.7	16.5	4.8	7.65
3.5, 1	11.7	16.7	5	8.01
3, 0.5	11	16.6	5.6	7.35
3, 1.5	10.5	17.7	7.2	7.53
3, 1	10.7	17.5	6.8	7.34

VIII. EFFECT OF THE DISTANCE BETWEEN PARASITIC PATCHES AND THE FEED PATCH

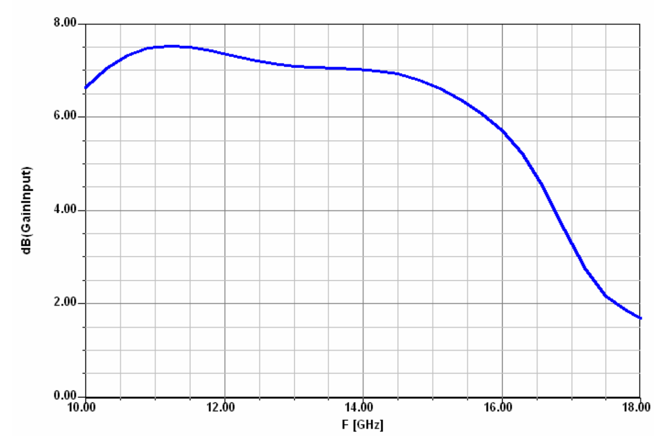
The effects of the distance between parasitic patches and feed patch are summarized in Table 3. As it shows S_1 and S_2 have important effects on the values of F_1, F_2 and Y. Decreasing the distances, $S_1 = S_2$, lead to decreasing F_1 and increasing F_2 and as a result the impedance bandwidth is increased. Meanwhile, Y is also increased by decreasing S_1 and S_2. For $S_1 = S_2$ = 0.8 mm, x = 3 and y = 1.5 the antenna has the maximum bandwidth of 7.6 GHz (53.9%) with a gain of 7 dB at 14 GHz. The variation of antenna gain and return loss are shown in Fig. 4A and 4B versus frequency respectively. Our numerical results also show that S_1 and S_2 have not important effects on the radiation patterns.

TABLE III

EFFECT OF THE SPACE BETWEEN PARASITIC PATCHES AND THE MAIN PATCH

S1=S2	F1	F2	Y	BW(GHz)	Max gain(dB)
1.5	10.7	17.5	1.6	6.8	7.5
1.2	10.6	17.6	1.76	7	7.53
1	10.45	17.75	1.87	7.3	7.53
0.9	10.4	17.8	1.94	7.4	7.53
0.8	10.3	17.9	2	7.6	7.53

(a)



(b)

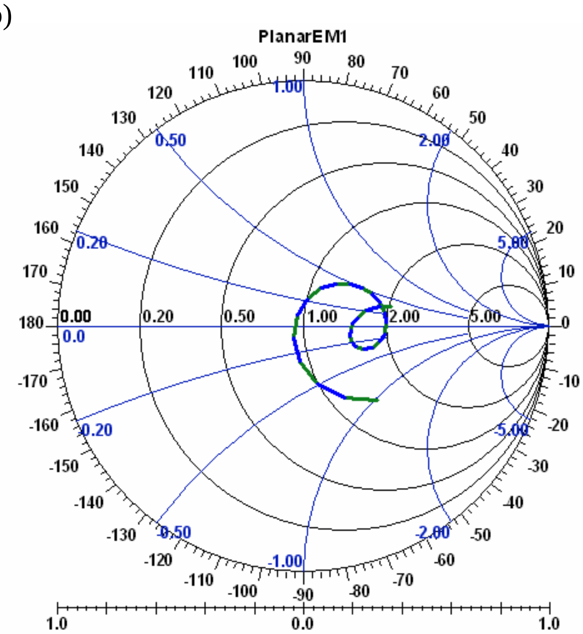


Figure 4. A: Gain plot of the antenna B: Smith chart plot of return loss of the antenna

IX. Conclusion

In this paper a multilayer, multiresonator microstrip antenna was numerically investigated using MoM. The effects of adding parasitic patches, feed location and distance between different patches on the radiation characteristics were studied. The results show the whole structure presents impedance bandwidth of 7.6 GHz (53.9%) with a gain of 7 dB at 14 GHz which is quite useful for application of ultra wideband communication systems. However, an optimization procedure is needed to consider other characteristics of the structure such as radiation patterns of the antenna and also design of the structure in other frequencies.

Acknowledgment

The authors would like to thank Iran telecommunication research center (ITRC) for its financial supports. The first author wishes to thank Mr. Y. Zehforoosh for all the discussions.

References

[1] T. A. Milligan, *Modern antenna design*, John Wiley & Sons, Hoboken, New Jersey, 2005.
[2] R. Garg, P. Bhartia, I. Bahl and A. Ittipiboon, *Microstrip antenna design handbook*, , Artech House, Boston, London, 2001.
[3] G. Kumar and K.P.Ray, *Broadband microstrip antennas*, Artech House, Boston, 2003.
[4] K. L. Wong, *Compact and broadband microstrip antenna*, John Wiley & Sones, New York , 2002.
[5] L. Inclan-Sanches, E. Rajo-Iglesias, V. Gonzalez-Posadas, and J.L. Vazquez-Roy, "Design of periodic metallo-dielectric structure for broadband multilayer patch antenna," *Microwave and optical technology letters*, Vol. 44, No. 5, March 2005, pp. 418-421.
[6] K. P. Ray, S. Ghosh and K. Nirmala, "Multilayer multiresonator circular microstrip antennas for broadband and dual-band operation," *Microwave and optical technology letters*, Vol. 47, No. 5, December 2005, pp. 489-494.
[7] Y. Zehforoosh, Ch. Ghobadi, J. Nourinia, "Antenna design for ultra wideband application using a new multilayer structure, " Progress In Electromagnetics Research Symposium 2007, Beijing, China, March 26-30, pp. 2225-2231.
[8] Ansoft designer's help