Design Formula for Inset Fed Microstrip Patch Antenna

M. Ramesh and YIP KB

Motorola, PINANG, MALAYSIA

Abstract

This paper presents the transmission line model for analyzing the microstrip line inset fed patch antenna and also presents a curve fit formula for locating the exact inset length to obtain 50Ω input impedance. Accuracy of the formula is compared with the results obtained from the EM simulator.

1. INTRODUCTION

Modern communication systems demand for low cost and low profile antennas. Microstrip patch antenna is one of the candidate antennas meeting those requirements due to its conformal nature and capability to integrate with the rest of the printed circuitry. Feeding mechanism plays an important role in the design of microstrip patch antennas. A microstrip patch antenna can be fed either by coaxial probe or by an inset microstrip line. Coaxial probe feeding is some times advantageous for applications like active antennas, while microstrip line feeding is suitable for developing high gain microstrip array antennas. In both these cases, the probe position or the inset length determines the input impedance.

The input impedance behavior for coaxial probe fed patch antenna is well studied analytically using Transmission Line Model, Cavity model and Full wave analysis [1, 2, 3]. Experimentally and theoretically it has been found that coaxial probe fed patch antenna's input impedance exhibits $\cos^2\left(\pi \frac{y_o}{L}\right)$ behavior, where y_o is the position of the feed from the edge along the direction of the length (L) of the patch. On the other hand, experimentally [4], it has been found that on low dielectric constant materials, inset fed probe fed patch antenna's input impedance exhibits $\cos^4\left(\pi \frac{y_o}{L}\right)$ behavior. In Section 2 a simple analytical approach using Transmission line model is presented to find the input impedance of inset fed microstrip antenna. Using this approach, a curve fit formula is derived to find the inset length to achieve 50Ω input impedance.

2. ANALYSIS

Fig.1 shows the inset fed microstrip patch antenna. Let the substrate dielectric constant, thickness, patch length, patch width, feed line width and feed line inset distance be denoted

 ISSN 1516-7399

by ε_r, h, L, W, w_f and y_o respectively. Input impedance of the inset fed microstrip patch antenna mainly depends on the inset distance y_o and to some extent on the inset width (spacing between feeding line and patch conductor). Variation in the inset length does not produce any change in resonant frequency but a variation in inset width changes the resonant frequency. Hence in the following discussion, the spacing between the patch conductor and feed line is kept constant, equal to the feed line's width and variation in the input impedance at resonant frequency with respect to inset length is studied for various parameters.

Assuming the patch is divided into four regions, it can be modeled as transmission lines loaded by radiating slots of different length as shown in Figure 2. Parameters of each transmission line and the slot are given in Table 1. The radiating slots A, B and C can be modeled as discussed in [5].

Table 1. Parameters of elements in the model

Element	**Width**	**Length**
TL1	W	$L - y_o$
SLOT A	h	W
TL2	$\frac{W - 3w_f}{2}$	y_o
SLOT B	h	$\frac{W - 3w_f}{2}$
TL3	$\frac{W - 3w_f}{2}$	y_o
SLOT C	h	$3w_f$

Using the above approach a patch antenna with ε_r = 2.42, h = 0.127 cm, W = 5.94 cm, L = 4.04 cm and y_o = 0.99 cm has been analyzed. Fig.3 shows the comparison between the results obtained using the TLM method presented in this paper and those obtained using EM simulator. Even though there is a shift in the resonant frequency the present model tracks the return loss profile very closely. The small shift in the resonant frequency can be attributed for not considering the discontinuity between the inset feed line and the patch. This model is used to perform parametric studies of the patch for various values of $\varepsilon_r (2 \le \varepsilon_r \le 10)$. Fig.4. shows that rectangular microstrip patch antenna fed by a microstrip line at the edge (y_o = 0) will have higher input resistance varying approximately from 150 Ω to 450Ω for varying ε_r. Also it is observed that the input impedance falls rapidly as the inset position is moved toward the centre from the edge as compared to the coaxially probe fed patch antennas. These parametric studies have been used to derive the curve fit formula (1) to find the exact inset length to achieve 50Ω input impedance for the commonly used thin dielectric substrates.

$$y_o = 10^{-4}\left\{\begin{matrix} 0.001699\varepsilon^7{}_r + 0.13761\varepsilon^6{}_r - 6.1783\varepsilon^5{}_r + 93.187\varepsilon^4{}_r - 682.69\varepsilon^3{}_r + \\ 2561.9\varepsilon^2{}_r - 4043\varepsilon_r + 6697 \end{matrix}\right\}\frac{L}{2} \qquad -(1)$$

$$(2 \le \varepsilon_r \le 10)$$

Accuracy of the above formula has been checked for the patch with ε_r = 5.0, h = 0.127cm, W = 4.1325cm, L = 2.8106cm and y_o = 0.9009cm. To confirm the validity of the above

 ISSN 1516-7399

formula, this patch is analyzed using the EM simulator and Fig.5 shows the comparison of the present model and EM simulation results. Even though there is a shift of one percent in the resonant frequency, close agreement in the return loss profile can be noticed.

3. CONCLUSIONS

Application of the TLM to find the input impedance of an inset fed micrsotrip patch antenna is presented. A curve fit formula for finding the exact inset length to obtain 50Ω input impedance is presented.

Acknowledgements

The comments of Motorola iDEN group members are gratefully appreciated by the authors.

References

[1] Carver.K.A., Mink.J.W., “Microstrip antenna technology”, IEEE Trans. Antennas Propagat, Vol.29, pp.2-24, Jan. 1981

[2] Pues.H., Van De Capelle.A, “Accurate transmission line model for the rectangular microstrip antenna”, IEE Proc. H, Microwaves, Optics & Antennas, 1984, Vol.134, PP.334 – 340

[3] D. M. Pozar, “Input impedance and mutual coupling of rectangular microstrip antennas”, IEEE Trans. Antennas Propagat., vol. AP-30, pp.

[4] 1191–1196, Nov. 1982.

[5] Lorena I. Basilio, Michael A.Khayat, Jeffery Williams, Stuart A.Long, “The Dependence of the Input Impedance on Feed Position of Probe and Microstrip Line – Fed patch Antennas”, IEEE Trans. Antennas Propagat, Vol.49, pp.45-47, Jan. 2001

[6] Daniel H. Schaubert, Frederick G. Farrar, Arthur Sindoris and Scott T. Hayes, “Microstrip antennas with frequency agility and polarization diversity”, IEEE Trans. Antennas Propagat., Vol. 29, pp. 118-123, Jan. 1981.

 ISSN 1516-7399

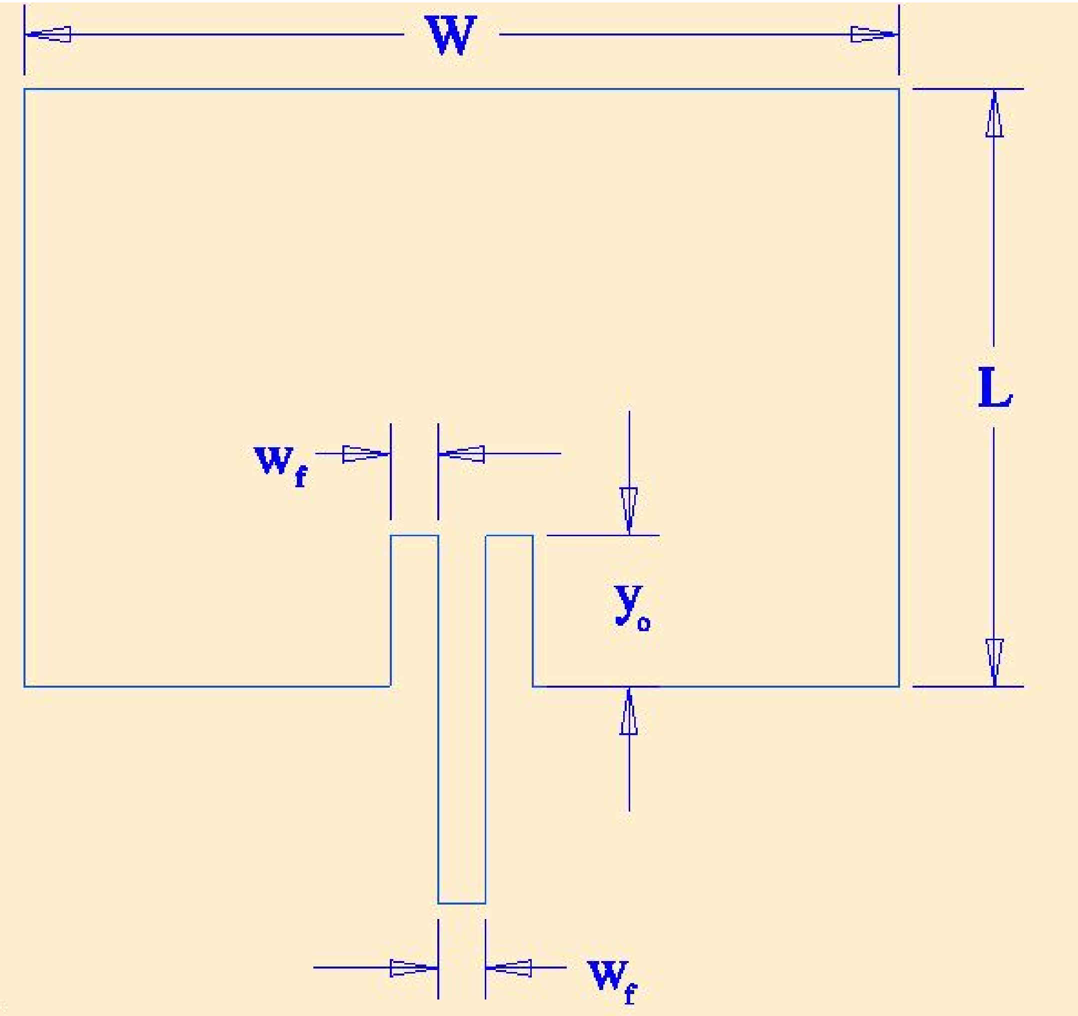


Fig.1 Inset Fed Microstrip patch antenna

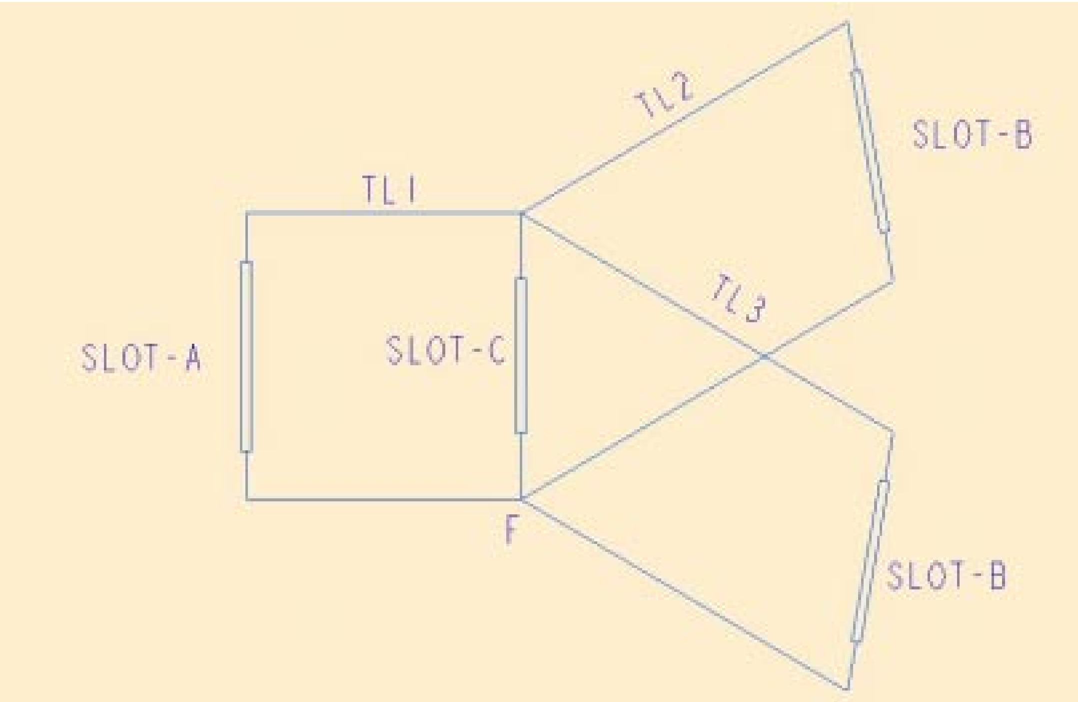
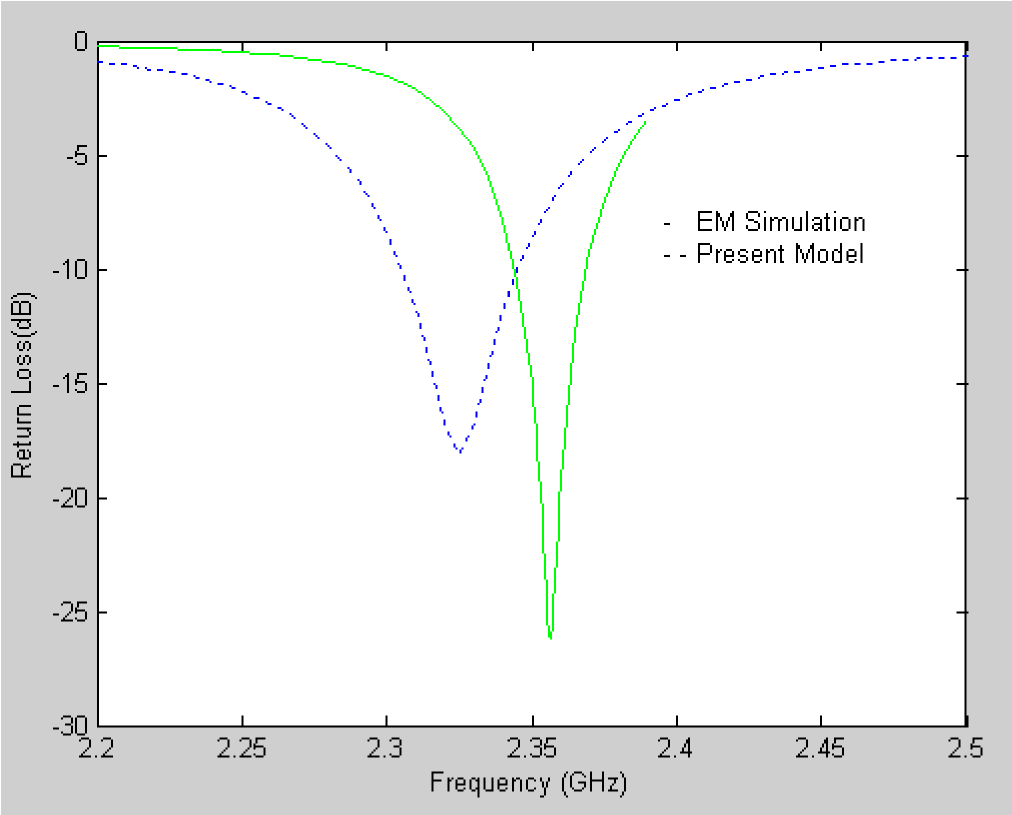
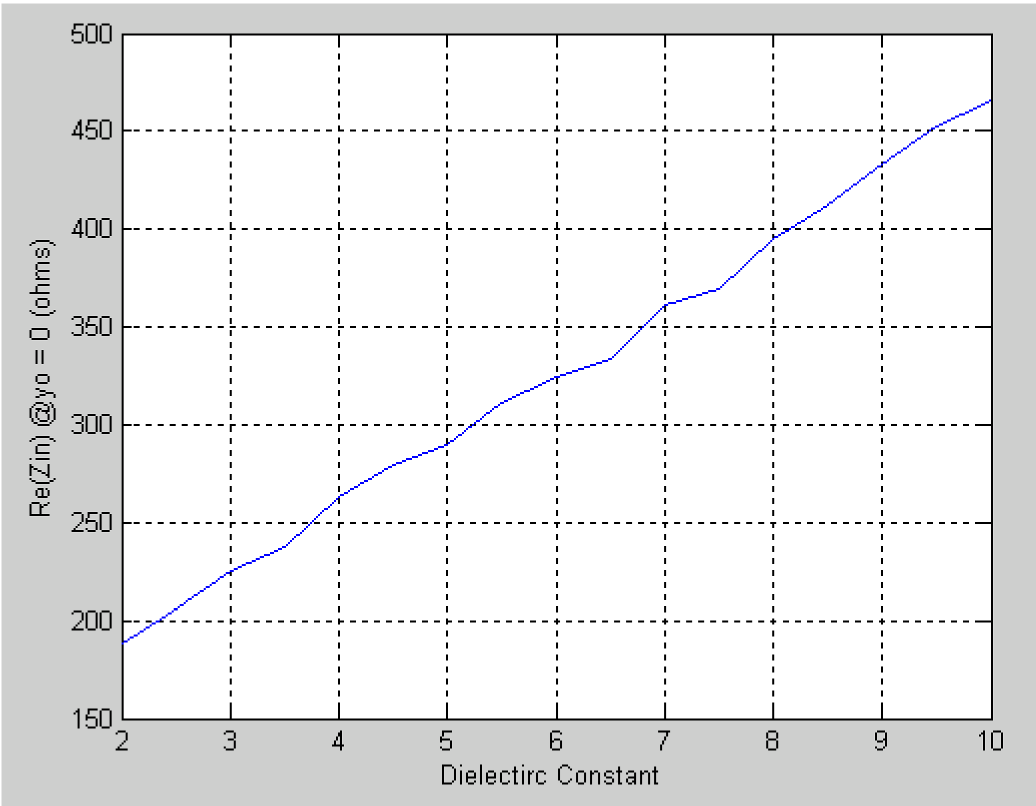


Fig.2 Equivalent Circuit



0
-5
-10
-15
-20
-25
-30
Return Loss(dB)
2.2
2.25
2.3
2.35
2.4
2.45
2.5
Frequency (GHz)
- EM Simulation
- - Present Model

Fig. 3



500
450
400
350
300
250
200
150
Re(Zin) @yo = 0 (ohms)
2
3
4
5
6
7
8
9
10
Dielectirc Constant

Fig.4

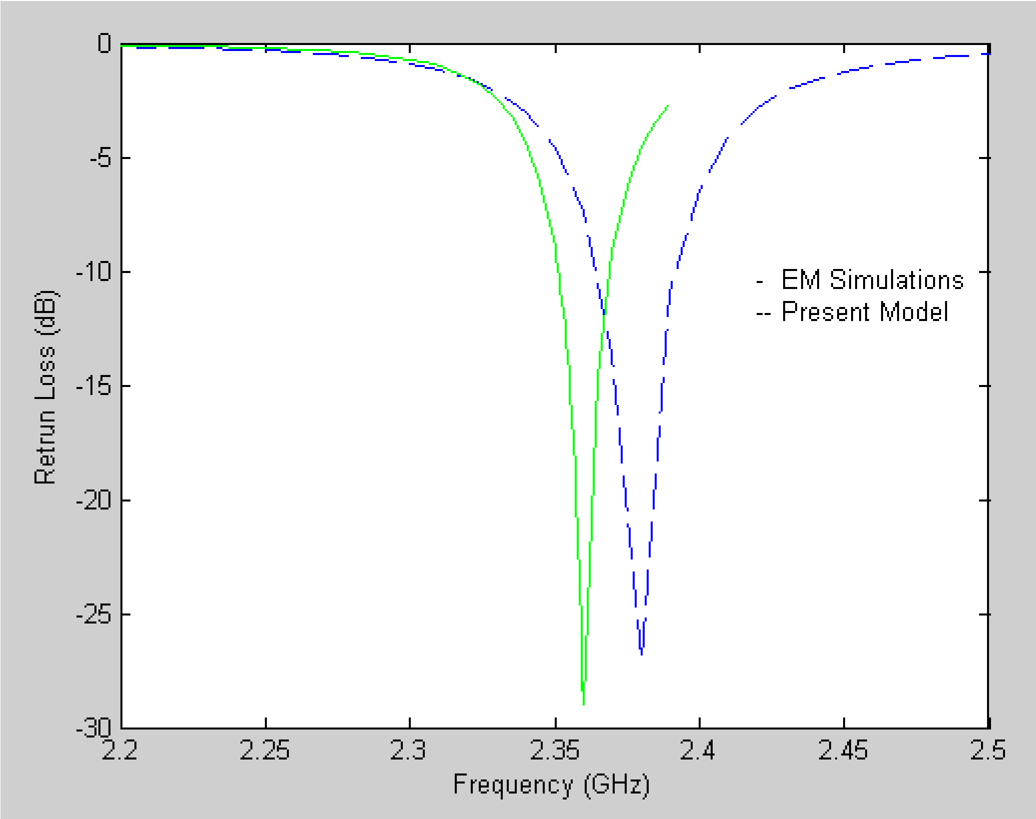

0
-5
-10
-15
-20
-25
-30
2.2
2.25
2.3
2.35
2.4
2.45
2.5
Retrun Loss (dB)
Frequency (GHz)
- EM Simulations
-- Present Model

Fig.5