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The Effect of LHM Slot to 2.4 GHz Rectangular Microstrip Patch Antenna

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ABSTRACT-- *This paper describes about rectangular microstrip patch antenna using Left Handed Metamaterial (LHM) method operates at frequency 2.4 GHz. This method is designed on substrate made from FR4 and substrate thickness is 1.6 mm. Etched on antenna ground plane that its size is 49x49 mm, LHM method is used to reduce VSWR and retun loss. In this study, slot iteration is on ground plane toward LHM and starts from upper to lower side, left to right side of ground plane. Iteration size is about 1 mm to 4 mm but LHM size is constant. The simulation results show LHM method reduce VSWR and Return Loss. The slot size in relation to VSWR and Return loss is linear, the smaller the slot size is iterated, the lower return loss and VSWR is yielded. The lowest Return loss and VSWR are about -47.34 dBi and 1,009 at frequency operates 2.4 GHz, obtained at ground plane slot distance to LHM is 1 mm.*

Keywords*—effect, rectangular microstrip patch antenna*

I. INTRODUCTION

Microstrip antenna has the advantage of having a thin cross-sectional area, easy to manufacture, small and lightweight in size and can be integrated with other communication devices. Besides having advantages, microstrip antenna also have the disadvantage of being narrow bandwidth, low efficiency, and requiring a high level of accuracy in calculation and design because of the small antenna size[1]. There has been a lot of research and development on this type of microstructure antenna, one of which is the use of metamaterial. Metamaterial have a material structure that has permittability and permeability that cannot be seen in nature around of us, double-negative material ($\varepsilon_r < 0$ and $\mu_r < 0$), *mu-negative material* ($\varepsilon_r > 0$ and $\mu_r < 0$) or *epsilon negative material* ($\varepsilon_r < 0$ and $\mu_r > 0$)[2]. This paper discusses the effect of slot the LHM structure on the ground plane of the rectangular microstrip antenna at frequency 2.4 GHz by iterating the slot on the LHM structure and the ground plane.

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II. ANTENNA THEORY

Rectangular microstrip patch antenna (RMPA) have substrates, patch, feed lines and ground planes as shown in figure 1[2][3].

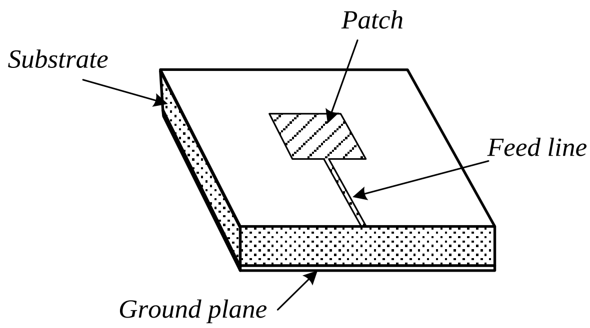

Figure 1: Rectangular microstrip patch antenna

Basically, rectangular microstrip patch antenna design can be done by calculating the patch size, feed line width and ground plane dimension using the following equations:

a. The wide (W) and length (L) of patch [4][5]:

$$W = \frac{c}{2 f_r \sqrt{\frac{(\varepsilon_r + 1)}{2}}} \tag{1}$$

$$L = L_{eff} - 2\Delta L \tag{2}$$

Where,

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{reff}}}$$

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

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12h/W}}\right)$$

c is free-space velocity of light (3×10^8 m/s), ε_r is dielectric constant of the substrate, f_r is resonant frequency, h is thickness of the substrate, L_{eff} is the effective patch length, ΔL is the length extension and ε_{reff} is the effective dielectric constant of the substrate[4][5].

b. Feed line width (W_o) is obtained by adjusting the expecting characteristic impedance (Z_c) [4][5]:

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(3.a) (3.b)

Design on this paper expects the characteristic impedance of 50 Ohm.

$$Z_c = \begin{cases} \frac{60}{\sqrt{\epsilon_{\mathrm{reff}}}} \ln\left[\frac{8h}{W_0} + \frac{W_0}{4h}\right], & \frac{W_0}{h} \leq 1 \\ \frac{120\pi}{\sqrt{\epsilon_{\mathrm{reff}}}\left[\frac{W_0}{h} + 1.393 + 0.667\ln\left(\frac{W_0}{h} + 1.444\right)\right]}, & \frac{W_0}{h} > 1 \end{cases}$$

c. Ground plane dimension. The physical dimension of the ground plane are based on the following formulae[5]:

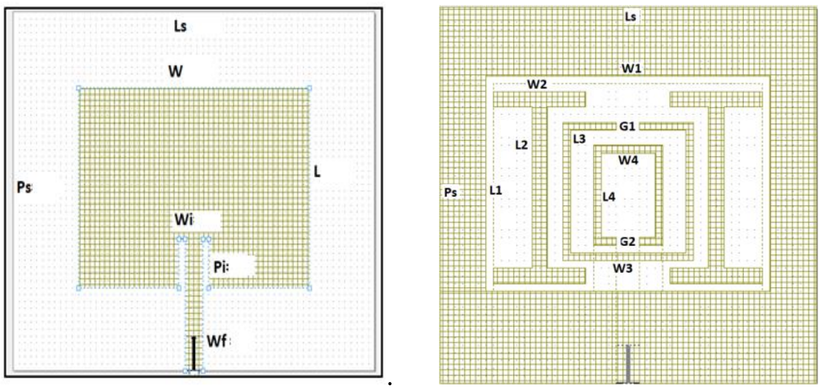
$$Lg = 6h + L \quad (4)$$

$$Wg = 6h + W \quad (5)$$

By using the values of the FR4 substrate having εr = 4.4 and h = 1.6 mm and the expected resonant frequency is 2.4 GHz, then a rectangular microstrip patch antenna design can be obtained based on equation (1) to (5).

III. ANTENNA DESIGN

The antenna uses two layers with FR4 substrate (εr = 4.4) substrate thickness of 1.6 mm and thickness of copper conductor layer 0.02. The top copper layer is a patch and the bottom copper layer is a ground plane. The design of the designed antenna can be seen as in Figure 2. Desired antenna specifications at 2.4 GHz operating frequency, return loss ≤ -9 dB and VSWR ≤ 2 can be seen in Table 1. The dimension of the rectangular microstrip patch antenna using LHM can be seen in Table 2.



Front view b. Back view

Figure 2: Design RMPA using structure LHM

Table 1: Antenna Specifications

No.	Parameter	Value
1	Frequency	2.4 GHz
2	Return Loss	≤9 dB
3	VSWR	≤ 2

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Table 2: Dimension RMPA using LHM

Parameter	Width (mm)	Length (mm)
Patch	35	27
Substrate	49	49
Inset	1	3
Feed line	3	7

IV. SIMULATION RESULTS

Rectangular microstrip patch antena with structure LHM is simulated using AWR simulator. Iteration is done from a slot of 1mm to 4mm from the left, right, top and bottom side of the LHM structure with a ground plane. Return loss graph simulation results of rectangular microstrip patch antenna design with LHM technique can be seen in figure 3 while the VSWR graph can be seen in figure 4.

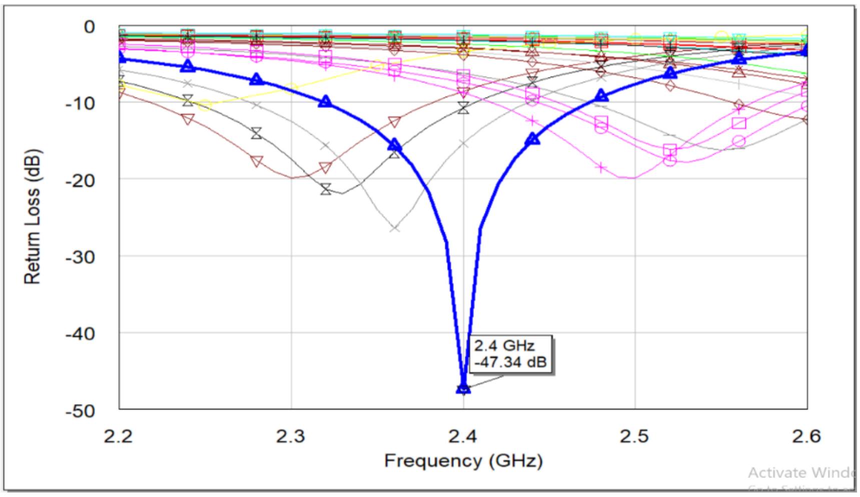

Figure 3: Return Loss (S_{11})

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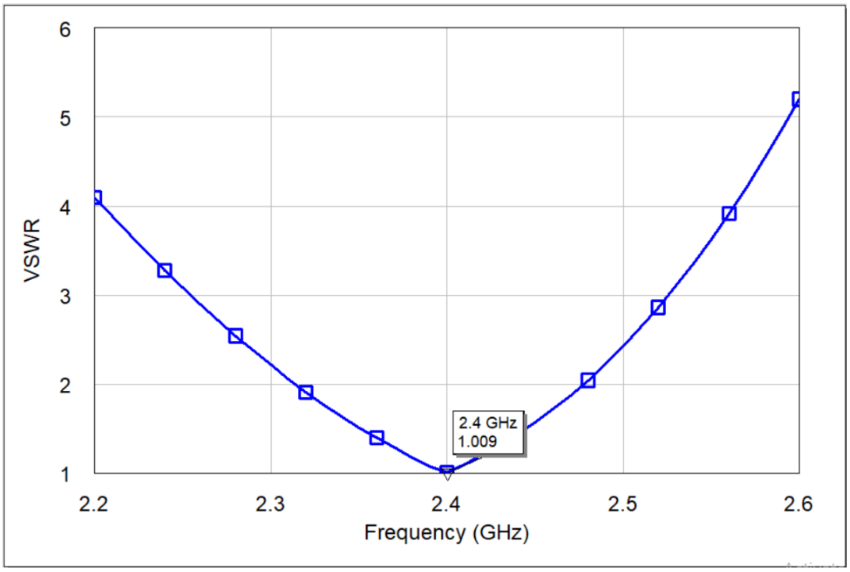

Figure 4: VSWR

Based on the iteration that has been done, it is obtained that the slot size results in the smallest return loss obtained at the smallest slot size, which is 1 mm. Return loss in the 1mm slot size is -47.34 dB while the smallest VSWR is 1.009 at the frequency 2.4 GHz.

V. CONCLUSION

This paper discusses the effect of slot on the microstrip antenna with the left handed metamaterial (LHM). The impact by reducing the size of the slot on the LHM structure in the ground plane can reduce of the return loss to -47.34 dB and reduce of VSWR to 1.009 at the desired frequency 2.4 GHz, the smaller the slot between the LHM structure and the distance the ground plane makes the return loss and VSWR parameters get better.

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