Design of 2 by 2 Planar Array Antenna Using Aperture Coupler Technique

H. Alias
Faculty of Electrical Engineering,
Universiti Teknologi MARA Malaysia
40450 Shah Alam, Selangor, Malaysia.
hafiza.alias89@gmail.com

Abstract—**This paper presents a design of 2 by 2 planar array microstrip antenna with a non-contacting feed. The type of non-contacting feeding used is aperture coupler technique. The antenna is basically consists of two layer of substrates which called superstrate and substrate. Patches are printed on top of the superstrate while the feedline is located on the bottom of the substrate. The antenna is designed at 5.8 GHz of frequency. The parameters in concern are the response of S_{11}, which is the return loss, and the radiation pattern. The design is first being simulated in CST Microwave Studio and then fabricated onto FR-4 to see the actual antenna's performance.**

Keywords – Microstrip antenna, aperture coupler, S_{11} parameter, radiation pattern

I. INTRODUCTION

In recent years, people go towards miniaturization of the electronic devices. With their small dimensions and their performances, microstrip antenna becomes more and more popular in wireless applications [4]. They are extremely compatible for embedded antenna that used in mobile devices such as cellular phones, pagers and others. Microstrip patch antenna often used in telemetry and communication antenna on missiles where the antenna need to be conformal and thin [2]. They are also used in satellite communications. Because of their proved effectiveness, they tend to replace the traditional antennas definitively [4].

Microstrip antenna is actually a resonant structure that consists of a dielectric substrate sandwiched between a metallic conducting patch and a ground plane. It is usually excited using a microstrip edge feed or a coaxial probe [1].

This printed antenna technology, which involved photo etching and press machining is suitable for low cost manufacturing. Some of other microstrip antenna's advantages [1-2] are light weight, low volume and low profile planar configuration [9]. The antenna can also be easily integrated with microwave integrated circuit (MICs) and capable of dual and triple frequency operation [3].

And of course, they do have some disadvantages such as low efficiency, low gain and low power handling capacity. Microstrip antenna also said to have surface wave excitation.

The greatest drawback of microstrip antenna is narrow impedance bandwidth. A method used to increase the impedance bandwidth is by using non-contacting feed [1]. This paper will discuss on a microstrip antenna that uses aperture coupled type of non-contacting feed.

This design uses two parallel dielectric layers separated by a ground plane. The lower dielectric layer is called substrate while the upper layer is called the superstrate. The patches are printed on top of superstrate and the feedline is on the bottom of substrate. Four rectangular slits, represented the aperture, were cut into a ground plane located between the dielectric layers. The feedline is coupled through the apertures.

II. DESIGN

The patches are of length L and width W. The substrate and the superstrate are of the same material and dielectrics. The material used is FR-4 with dielectric constant, ε_r, 4.7. The thickness of superstrate and substrate are 1.6mm each. The size of the feedline was adjusted to make sure that the impedance of the antenna is 50Ω. The size of the slits may also affect the impedance. However, the size of the aperture should be as small as possible to shield the patch radiator from feed effect [11].

Quarter transformer wavelength of size 4x4(mm) was placed so that a total of 50Ω impedance is distributed at each of feed end [4]. The equations used to calculate the antenna parameters are as below:

$$W = \frac{c}{2fr\frac{\sqrt{(\varepsilon r+2)}}{2}} \qquad (1)$$

$$L = L_{eff} - 2\Delta L \quad (2)$$

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r+1}{2}\left[1 + 12\,\frac{h}{w}\right]^{-1/2} \quad (3)$$

$$L_{eff} = \frac{c}{2\,fr\,\sqrt{\varepsilon reff}} \quad (4)$$

$$\Delta L = 0.412h\,\frac{(\varepsilon reff+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon reff-0.3)\left(\frac{w}{h}+0.813\right)} \quad (5)$$

$$Wt = exp^{\frac{Zc(\sqrt{\varepsilon r+1.41})}{87}}\,\frac{5.98\,h}{0.8} \quad (6)$$

Where,

- W = Width of patch
- L = Length of patch
- f_r = resonant frequency
- h = Thickness of substrate
- ε_r = Dielectric constant
- c = Speed of light
- Z_c = Impedance of transmission line
- ε_{reff} = Effective dielectric constant
- L_{eff} = Effective length
- ΔL = Length extension
- w_t = Width of transmission line

The calculated values of the parameters are as tabulated in Table 1 below. However, in simulation, those parameters have to be tuned to get a better and more accurate antenna response. The actual or final values used in simulation also tabulated in Table 1.

TABLE 1: SPECIFICATION OF 2X2 PLANAR ARRAY ANTENNA USING APERTURE COUPLER

Quantity	Calculated Value	Final value
Patch length, L (mm)	11.63	8.98
Patch width, W (mm)	20	17.9
Feedline width (mm)	5.8	3.9

A single patch microstrip antenna is first designed. This design is used to be as the benchmark to design the four patches 2 by 2 planar array antenna. The single patch antenna as shown in Figure 1, is the design used in simulation, to get a resonant frequency of 5.8GHz.

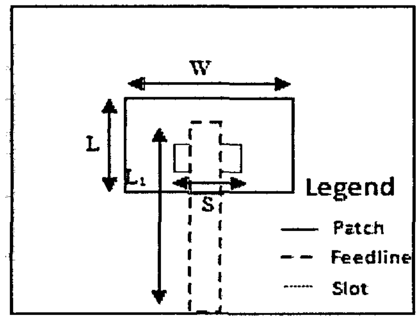


Figure 1: Design of single patch antenna

Other parameters such as length of feedline, L_1 and width of slot, s were determined by try-an-error

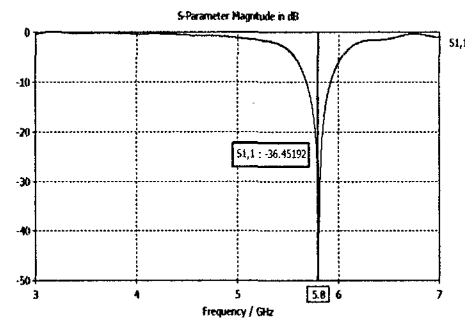


Figure 2: S_{11} response of single patch antenna using aperture coupler technique

The calculated antenna specification is then used again to design a 2 by 2 planar array antenna. The same size and position of the slot is plotted. The actual size and measurement of the antenna is as shown in Figure 3. L_1 and W were tuned to get the best response of S_{11} that falls on the resonant frequency of 5.8GHz, as shown in Figure 4 (a) and (b).

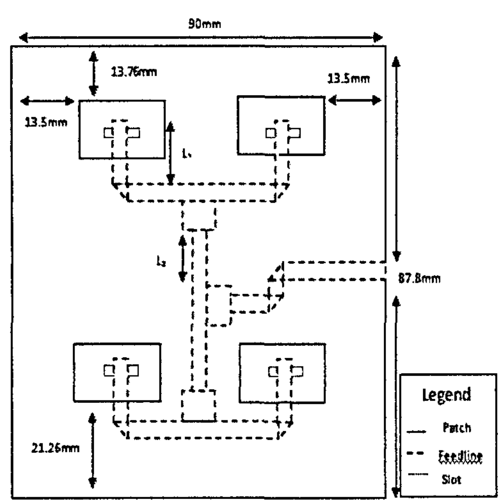
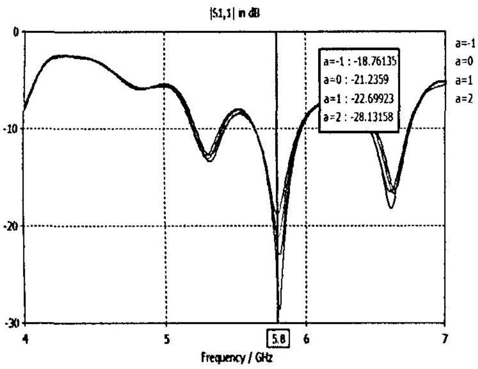
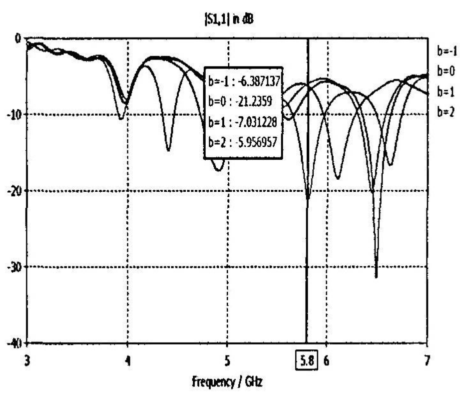


Figure 3: Design of 2 by 2 Planar Array Antenna Using Aperture Coupler Technique



(a)

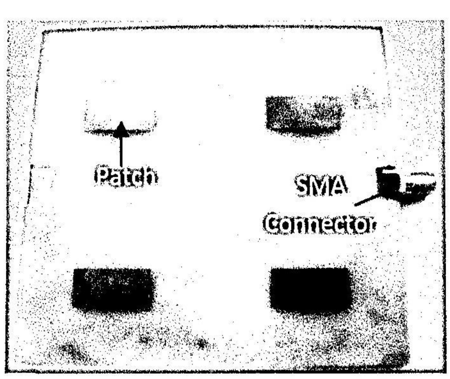


(b)

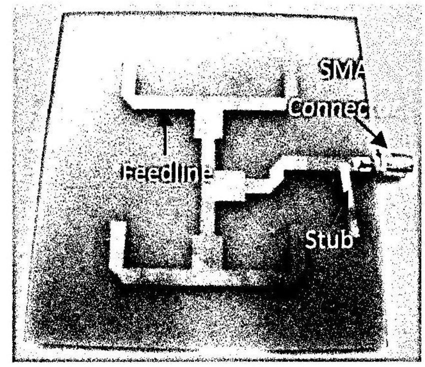
Figure 4: Optimization process. (a) Slot size, a. (b) Size of patch, b

By optimizing and adjusting the interelement spacing between patches and slot sizes, the simulated S_{11} response and radiation pattern were given as in Figure 6 and 7.

After obtaining a satisfying response of S_{11} and radiation pattern, the design were fabricated on FR-4 board. The prototype is as shown in Figure 5 below:



(a)



(b)

Figure 5: Antenna's prototype. (a) Top view. (b) Bottom view

III. RESULT

The parameter of the fabricated antenna is then measured using vector network analyzer (VNA). The results were tabulated as Table 2 below:

TABLE 2 : RESULT OF S_{11} FROM SIMULATION AND MEASUREMENT

Parameter	Simulation	Measured	Measured (With stub matching)
Resonant frequency (GHz)	5.8	6.3	5.8
Return loss, S_{11}, (dB)	-21.59	-27.738	-20.857

Table 2 shows the resulted resonant frequency and return loss from simulation and measurement.

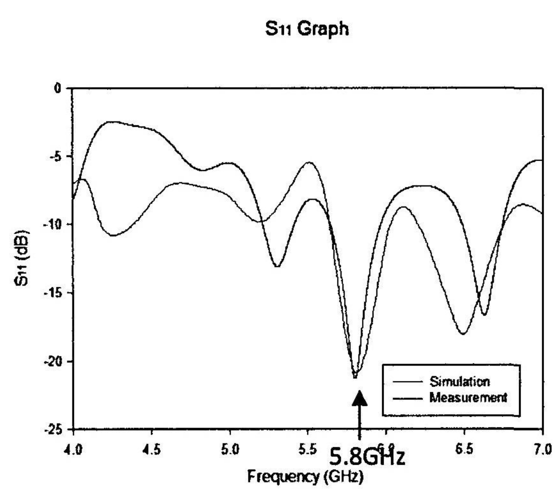


Figure 6: Result of S_{11} parameters

Another parameter that had been watched is radiation pattern of the antenna. The result from simulation is as in Figure 7.

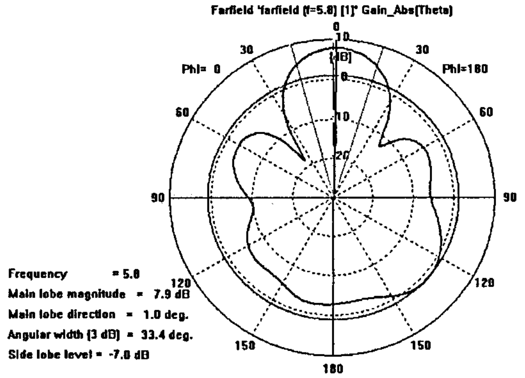


Figure 7: Radiation pattern result from simulation

IV. DISCUSSION

From Table 2, it is shown that the resonant frequency was first measured to be shifted to 6.3GHz. This condition happens due to losses occurred during fabrication. To overcome this discrepancy, stub matching technique was used. The resonant frequency was then falls back to 5.8GHz to give a return loss of -20.857dB. As for antenna, the higher the return loss, the lower reflection is and the better the performance of antenna.

Stub matching is a technique where a stub (copper strip) is added to the feedline to produce pure reactance to the point of attachment [10]. The length of stub matching is determined by try-an-error. The total length of stub that gives a resonant frequency of 5.8GHz is 16mm.

Figure 4 shows that the best working frequency for the antenna is 5.8GHz. However, from the measurement, the result shows that the antenna is a dual band antenna. It can also operate at 6.7GHz.

The radiation pattern obtained from simulation, as in Figure 7, shows that the gain is 7.9dB which is acceptable. However, the back lobe is quite big for an antenna. This is mainly because of the feedline that is situated at the bottom layer of the substrate. However, measurement to determine radiation pattern of the antenna's prototype cannot be carried out due to the lack of tools and equipments.

V. CONCLUSION

Microstrip antenna discussed in this paper is different from conventional microstrip antenna as it has feedline and patches on different layer of substrates. This way, radiation arising from feedline cannot interfere with the main radiation pattern generated by the antenna [8]. The antenna was designed to have a good return loss and radiation pattern. The corresponding return loss obtained from simulation is -21.59dB and from measurement is -20.857dB, while the resulted gain is 7.9dB.

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