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Dual Frequencies Band and Enhanced Wideband Effect of Dual Layer Microstrip Patch Antenna with Parasitic

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Abstract. In current telecommunication situation, the antenna with wideband or multi-band effect are important for cater many users' demands. In this research, the works explores the effect of parasitic element on the above of the dual layer microstrip patch antenna. Firstly, a basic microstrip patch antenna with a single layer of substrate (Design A) had been simulated using the CST Microwave Studio software. After that, the addition of another layer of substrate with parasitic element is shown as Design B. This proposed microstrip patch antenna resonates at two different frequencies of 2.396 GHz and at 2.543 GHz of frequency with – 36.8 dB and – 35.644 dB of return loss, respectively. The gain performance for both resonant frequencies at 2.396 GHz and at 2.543 is 5.035 dB and 4.814 dB, respectively. The bandwidth of the Design B antenna is 0.097 GHz (2.354 GHz – 2.451 GHz), had been increase compare with Design A performance of 0.039 GHz (2.380 GHz– 2.419 GHz). The second resonant frequency for Design B is only 0.028 GHz. (2.526 GHz– 2.554 GHz).

1.Introduction

Future telecommunication systems would be accomplished of accommodating higher data rates than the recent systems because of the various user demands from different segments. There is several of antenna design that had been investigating and fabricated earlier. The categories of antenna basically depend on the frequency range or band, the location and the application that the user desires to apply. One of the favorite types is the microstrip patch. Microstrip patch antenna is used in many applications such as handphone, Wi-Fi connection, and satellite communication due to their light weight & low profile.

In the previous design, there are many techniques to create the dual-band or multi-band frequency effect to the microstrip patch antenna. For examples, in [1] using fractal-like geometrical structure and in [2], the researcher using modified fractal slot antenna that fed by coplanar waveguide (CPW) technique. In [3], the author used the U-shaped slot and also two mitered corners to achieve dual frequency bands. In [4], dual band L-shaped had been apply in microstrip patch antenna. Lastly, T-shaped parasitic elements effect a dual-band frequency for the microstrip antenna [5], shorted parasitic element for dual-band monopole antenna [6], novel parasitic-element at printed antenna [7], and parasitic element at WLAN Yagi-Uda antennas [8]. There are other antenna designs that apply of parasitic element at their design such as in these several papers [9-17].

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The multi-band range antenna is highly in demand by users because of multi frequency or multiband application in one device. For example, the common dual applications that using a single antenna is the combination of the Wireless Local Area Network (WLAN) at 2.4/5.2 GHz and Worldwide Interoperability for Microwave Access (WiMAX) at 3.6/5.8 GHz [18-24]. The WLAN application is the common communication band that used currently, especially in the mobile phone, smart television and personal computer, iPad and laptop. This technology is easy to use and fabricated in the printed microstrip patch antenna design.

Multilayer or dual-layer substrate in microstrip patch antenna design is another technique to improve the performance of the antenna. For example, in [25], it stated that the dual layer stacked is effect to exist the ultra-wideband to the rectangular microstrip patch antenna. This technique gives a wider bandwidth of 56.8% in the between 3.06 GHz and 5.49 GHz of the resonant frequencies to the antenna performance. In [26], the two layers substrate and loop antenna with air gap had been effect two different frequencies of the antenna at 1.5 GHz and 2.0 GHz

There are many examples of microstrip patch antenna design with parasitic element had been research before. For example, in [27], the simple single shaped of parasitic element with two orthogonal bowties had been increase the bandwidth of the circular polarized cross dipole antenna in between 1.9 GHz and 3.9 GHz. It also effects to enhance a 3-dB axial ratio of the antenna. In the other paper [28], the parasitic element had been increase the gain of the antenna. The design is using parasitic element for dual feed microstrip array antenna. In this case, the parasitic element had been effected to increase 2 dB (from 12.9 dB to 14.9 dB) of gain to the antenna design.

In [29], the parasitic element effects the triband frequencies to the patch antenna. The band effect is for Universal Mobile Telecommunications System (UMTS) band (1.9 GHz to 1.979 GHz), ISM band (2.4 GHz to 2.4835GHz) and the Long-Term Evolution band (LTE) (2.5 GHz to 2.57 GHz). This parasitic element also effect to improve the bandwidth of the patch antenna. In [30], the author successfully shows the improvement of the bandwidth of the compact transverse bilateral helical antenna using parasitic element. It stated that the antenna achieves 105% wider bandwidth in a 50-Ω reference system. Beside multiband effect, the parasitic element also can effect to miniaturize the size of the printed microstrip patch antenna. In [31], the microstrip patch antenna with compact size designed by using two rectangular U-shaped parasitic elements. This antenna size is 40.0 mm x 30.0 mm and resonates at the three different frequencies of 2.6 GHz, 6.0 GHz, and 8.5 GHz with bandwidth of 50 MHz, 22.8 MHz and 30 MHz, respectively.

In this paper, dual frequencies band microstrip patch antenna had been design using parasitic elements and dual layer of FR-4 substrate. The performance of the resonant frequencies return loss, bandwidth, gain and radiation pattern are the parameters that consider in this paper.

2.Antenna Design

This section illustrates the dimension and configuration structure of the proposed microstrip patch antenna. Figure 1 represents the design of the dual layer microstrip patch with parasitic element. This design contains two main layers of substrates with dimension of 56.0 mm width x 50.2 mm length. The first layer consists a basic patch antenna (38 mm width x 27.8 mm length) and feedline (3.1 mm width x 17.7 mm length).

For the second layer (above layer), the substrate is consisted with a parasitic element (33 mm width x 21.6 mm length) and a cut-off substrate (5.1 mm width x 25.1 mm length). This proposed antenna was designed using FR-4 substrates with permittivity, $\varepsilon r = 4.3$.

The design started with the basic rectangular patch antenna, shown by Design A. This basic rectangular patch is in the antenna with single layer of FR-4 substrate with 0.035 mm thickness of copper at the ground plane, shown as Figure 1(a).

The Design B is combination of the Figure 1(a) and Figure 1(b) with the patch antenna and parasitic elements. The parasitic element is located at the upper layer and did not connect with the patch antenna in the bottom layer. This parasitic element is effect to improve the bandwidth of the antenna and to create another resonant frequency.

Figure 1(c) shows the perspective view of the proposed antenna with dual layer of FR-4 substrate that consist a patch antenna and parasitic element. The full dimension copper ground is located at the back of the first layer of the substrate, same in the Design A.

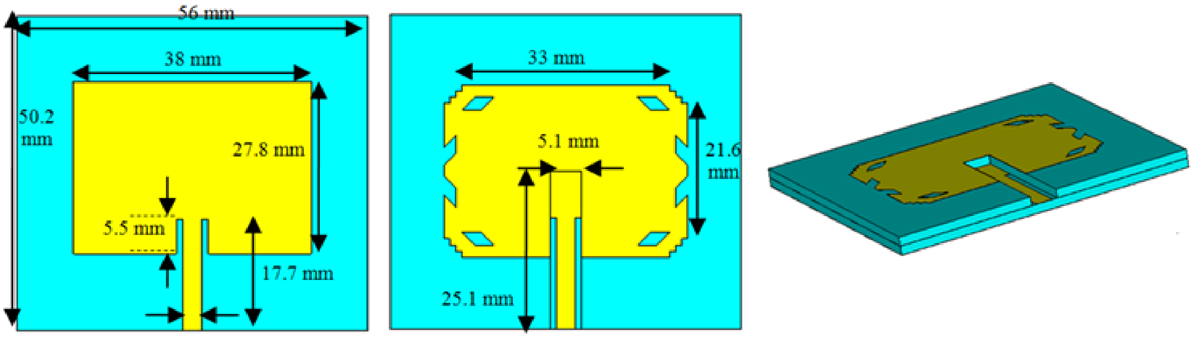

Figure 1. Dual layer microstrip patch antenna with parasitic element, (a) first layer of patch antenna and feedline – represent Design A, (b) Above layer with parasitic element and cut-off substrate – the combination of two layer represent Design B, (c) Perspective view of the antenna with dual layer of FR-4 substrate

3.Result

This section represents the result of the proposed microstrip patch antenna. The significant parameters that are considered in this research are resonant frequency (in GHz), return loss (in dB), bandwidth (in GHz), and antenna gain (in dB). Figure 2 shows return loss performance of the proposed antenna. It shows that, the resonant frequency of Design A antenna is at 2.4 GHz with a return loss of – 27.051 dB. With the addition of the second layer with parasitic elements (Design B), it creates a new resonant frequency at 2.543 GHz with – 35.644 dB. The second resonant frequency is narrower compared with the first resonant frequency.

It also remains the first resonant frequency at 2.396 GHz (shifted 0.004 GHz from 2.4 GHz) with return loss of - 35.644 dB. So, the addition of the parasitic element had been effected to increase the bandwidth from 0.039 GHz to 0.097 GHz while effects to enhance the return losses at the resonance frequencies while create new resonant frequencies for the antenna. Table 1 shows the resonant frequency, return loss performance of the proposed antenna. It shows that the Design B had been enhanced its bandwidth at the first resonant frequency compare with Design A, from 39 MHz to 97 MHz. The bandwidth of the second resonant frequency at 2.543GHz for Design B is only 28 MHz.

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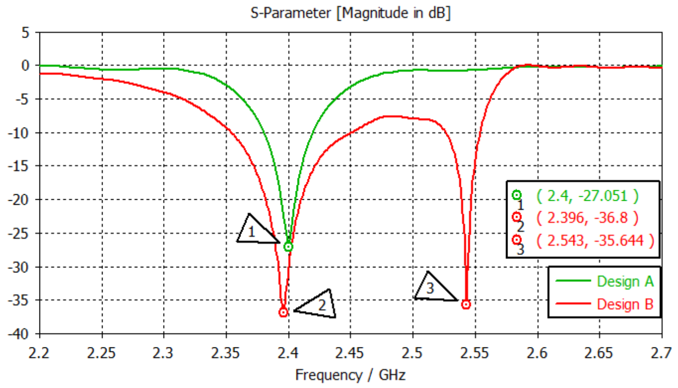

Figure 2. Return loss performance of the basic microstrip patch antenna for Design A and proposed microstrip patch antenna with parasitic element, Design B

Table 1. Resonant frequency, return loss and bandwidth of the microstrip patch antenna for Design *A* and Design *B*

Design	Resonant Frequency (GHz)	Return loss (dB)	Bandwidth (GHz), Frequency range (GHz)
A	2.400	- 27.051	0.039 (2.380 – 2.419)
B	2.396	- 36.800	0.097 (2.354 – 2.451)
	2.543	- 35.644	0.028 (2.526 – 2.554)

Figure 3 shows the radiation pattern effect for the resonant frequencies of 2.396 GHz and 2.543 GHz of Design *B* antenna at phi = 90^0. It shows that both resonant frequencies show the circular shape of the radiation pattern towards to the above part of the graph.

Figure 4 shows the 3D radiation pattern and gain performance effect of 2.396 GHz and 2.543 GHz of Design *B* antenna with 5.035 dB and 4.814 dB of antenna gain, respectively. Compare with the gain performance of Design *A* at 2.4 GHz, it shows the result of 5.014 dB, nearly the gain performance of Design *B* at 2.396 GHz.

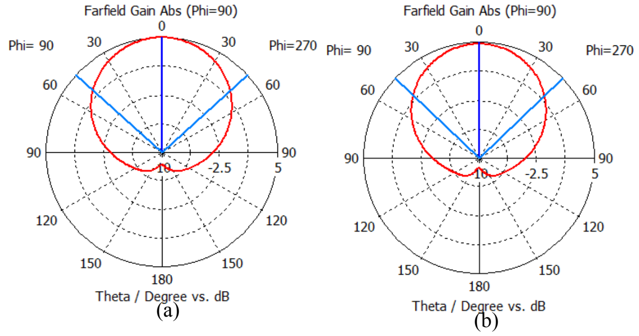

Figure 3. Radiation pattern effect for the resonant frequencies at phi = 90^0 of (a) first resonant frequency of 2.396 GHz and (b) second resonant frequency of 2.543 GHz of Design *B* antenna.

Table 1 shows the resonant frequency, return loss performance of the proposed antenna. It shows that the Design *B* had been enhanced its bandwidth at the first resonant frequency compare with Design *A*, from 39 MHz to 97 MHz. The bandwidth of the second resonant frequency at 2.543GHz for Design *B* is only 28 MHz.

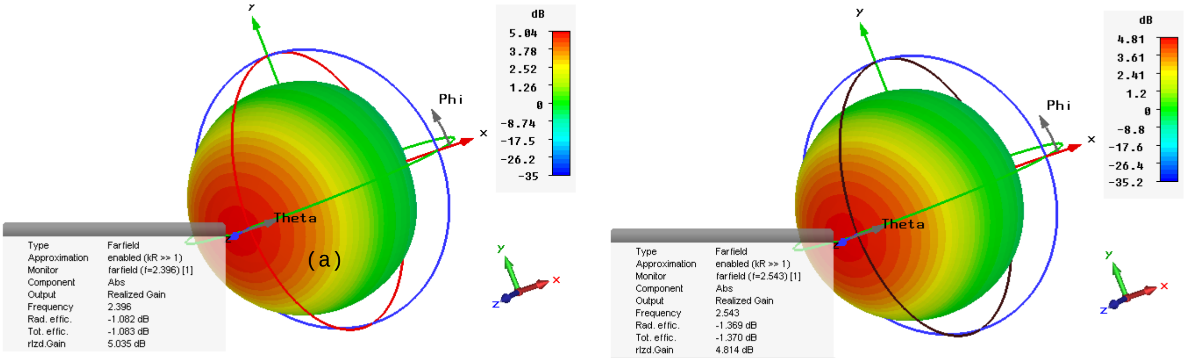

Figure 4. 3D radiation pattern and gain performance effect at the resonant frequencies of (a) 2.396 GHz and (b) 2.543 GHz of Design B dual-band microstrip patch antenna with parasitic elements.

Figure 5 shows the surface current distribution (for 0^0 and $90^{0)}$ of the dual-band antenna with parasitic element two different resonant frequencies at 2.396 GHz and 2.543 GHz. The figure represent that the surface current is computed a large number at patch antenna and at the parasitic element, while a little number of amount the feedline. This antenna is successfully to radiate at these two different frequencies, based on the surface current distribution. The current is pump in from the power source via SMA connector to the feedline at the bottom of the patch antenna. Then from feedline, the current is distributed to the other place of the patch antenna.

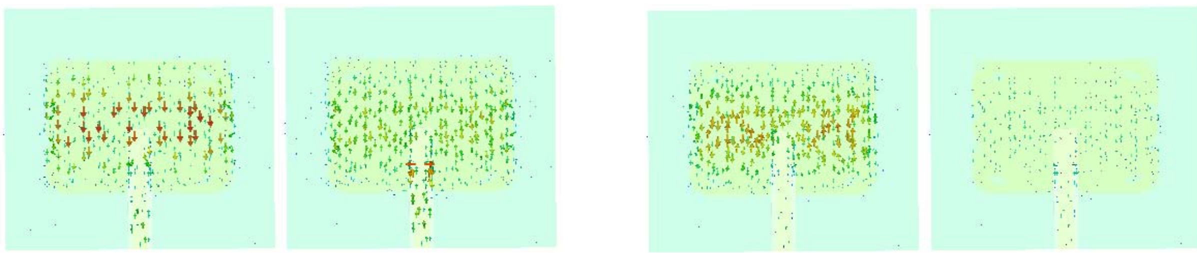

Figure 5. The surface current distribution of the dual-band antenna with the parasitic element. Two different resonant frequencies at (a) 2.396 GHz (for 0^0 and 90^0) and (b) 2.543 GHz (for 0^0 and 90^0).

4. Conclusion

After simulation work of dual-band antenna with the parasitic element done in this research, the author founded that the addition of the parasitic element structure successfully to enhanced the performance of the return loss of the first resonant frequency of 2.4 GHz (Design B). The addition of parasitic elements to the patch antenna also successfully creates a new resonant frequency at 2.543 GHz. It also shows the increasing the bandwidth from 39 MHz for Design A to 97 MHz to Design B. For the gain antenna, this addition structure did not give the significant effect, with only the increment of 21 MHz at the first resonant frequency.

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