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Wide to multiband elliptical monopole reconfigurable antenna for multimode systems applications

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Abstract

Wideband-multiband reconfigurable elliptical monopole antenna is investigated in this paper. By having conventional elliptical monopole antenna, wideband operating frequency is obtained. With the combination of dual pairs of slotted arms and a band-pass filter on the ground plane of the elliptical monopole, multiband is achieved. Dual-band operating frequencies at 1.6 GHz and 2.6 GHz while wideband operates from 3.35 GHz to 9 GHz. Therefore, wide range of wireless communication systems is obtained from the proposed antenna to support the multiband mode (i.e. GPS and LTE) and UWB systems. Frequency reconfigurable is achieved by controlling the switches integrated on the antenna structure. Simulated results of reflection coefficient, radiation patterns and gain performance are presented. The proposed antenna design is suitable candidate for different wireless communication applications.

Keywords: *band-pass filter, multiband antenna, reconfigurable, wideband antenna*

1. Introduction

Reconfigurable antennas are still attracting the interest of many researchers in recent years. This is because these antennas give many benefits to improve the performance of RF front ends. Unlike conventional antennas [1-8] which has a fixed operating frequency or pattern types, reconfigurable antennas have the ability to varying its operating frequencies and also radiation pattern to satisfy the modern communication systems. Most of the antennas in [1-4] have a wideband operating frequency, using a mictrostrip patch antenna design to operate in Ultra-wide band (UWB) frequency range. Meanwhile, reported antennas in [5-8] only can operate in multiband frequency. Despite of having compact size of antennas, they did not have the ability to control the operating frequencies compared to reconfigurable antennas.

Reconfigurable antennas can have frequencies switching or tuning [9-19] and also changing its radiation pattern or beam steering [20-23]. Most of the reconfigurable antennas can be used in cognitive radio systems, where most of them are having wideband to narrowband reconfiguration. However, having only one frequency operating at one time, will restraint the antenna to function for different applications simultaneously. More functionality such as wideband to narrowband and multiband reconfiguration can be more suitable to serve in the rapid growth of communication systems nowadays.

Most antennas reported to work on narrowband to narrowband [9,10] and wideband to narrowband reconfigurations such as in [11,12]. There are also reported antennas that can reconfigure between wideband to multiband [13], multiband to another multiband [14,15] and multiband to narrowband [16-19] operating frequencies. Lately, single to dual and triple-band reconfigurations have been getting much interest from researchers. Some reported antennas in [18, 19] are able to switch their operating frequencies using a simple structure antenna design. Antenna in [18] using slotted bowtie antenna and two pairs of slot in the ground plane to create additional bands. Circular slotted with different radii is presented in [19] to have a different operating frequency when the switches are turned ON or OFF. Both of the antennas can work from 2.0 GHz to 7.0 GHz.

The best way to bias the switches are to have circuit simplicity, which means no via will be involved [14]. Thus, monopole antenna with coplanar waveguide (CPW)-feedline is a suitable

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solution to provide wideband operating frequency. In this paper, elliptical monopole antenna is chosen to become wideband radiator, integrated with the dual-pairs of slotted arm located at the ground plane to produce the multiband mode. In order to eliminate the harmonic frequency, produce by multiband radiator, band-pass filter is incorporated.

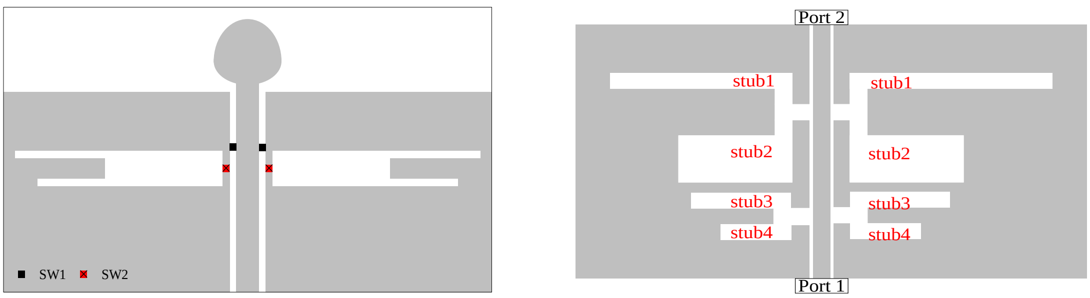
The antenna can operate at 1.6 GHz and 2.6 GHz in multiband mode while in wideband mode, the antenna can operate from 3.3 GHz to 9.0 GHz. Unlike antenna mentioned in [24], the antenna can only cover frequency range from 2.0 GHz to 6.0 GHz for both multiband and wideband mode. In other words, multiband operating frequency of antenna in [24], is within the wideband operating frequency too. However, the multiband operating frequency of the proposed antenna, is outside of the wideband operating frequency. Therefore, the proposed antenna in this paper can cover wider range of frequencies compared to antenna in [24]. Details of the antenna structure is explained in Section 2. The antenna performances including reflection coefficient, radiation pattern and gain are presented in section 3. lastly, this paper is concluded in section 4.

2. Antenna Structure

The design and simulation process are performed using CST® software. Initial antenna structure, will be called as antenna A, is shown in Figure 1 (a) while the band-pass filter consists of four stubs is shown in Figure 1 (b). Antenna A consists of elliptical monopole radiator, have a semimajor of A value and semiminor of B value, is fed by a CPW-feedline to produce wideband mode. Dual pairs of slot dipole arms (arm1 and arm2) together with rectangular box (boxR) is located in the ground plane to fully utilised the wideband antenna. In order to produce the multiband mode, the length of arm1 and arm2 are approximately quarter of wavelength of 1.6 GHz and 2.6 GHz, respectively. Wideband antenna is ranging from 3 GHz to 9 GHz while dual band antenna operates at 1.6 GHz and 2.6 GHz. The simulated reflection coefficient (S_{11}) results are shown in Figure 2 (a).

Band-pass filter as shown in Figure 1 (b) consists of four pairs of rectangular stubs. Two rectangular stubs are connected with one connecting part to reduce the number of switches. Parametric studies of this band-pass filter is presented in [25]. It produces pass band from 1.38 GHz to 3.29 GHz and stop band from 3.29 GHz to 9.0 GHz as shown in Figure 2 (b). By integrating the band-pass filter into the antenna structure, the filter will be able to eliminate the harmonic frequencies created by antenna A in the multiband mode.

Figure 3 illustrates the proposed antenna structure with the combination of antenna A and band-pass filter. The proposed antenna will later be called as antenna B. Antenna B using FR-4 substrate with a relative dielectric constant of 4.3 and thickness of 1.6 mm. The antenna consists of four pairs of switches. Two switches denoted as SW1 while the remaining switches are called as SW2. In this paper, ideal switch is used to achieve antenna reconfigurability. By switching ON SW1 and SW2 is turned OFF, multiband mode is achieved. In order to get wideband mode, SW1 needs to be turned OFF and SW2 is switched ON. Switch ON means copper strip is present while switch OFF means vacuum block is used to replace the copper strip. Table 1 represents the value of parameters used in designing the proposed antenna. Others parameters which are not shown here can be refered at [24].



(a) (b)

Figure 1. The structure of (a) Antenna A (b) band-pass filter [25]

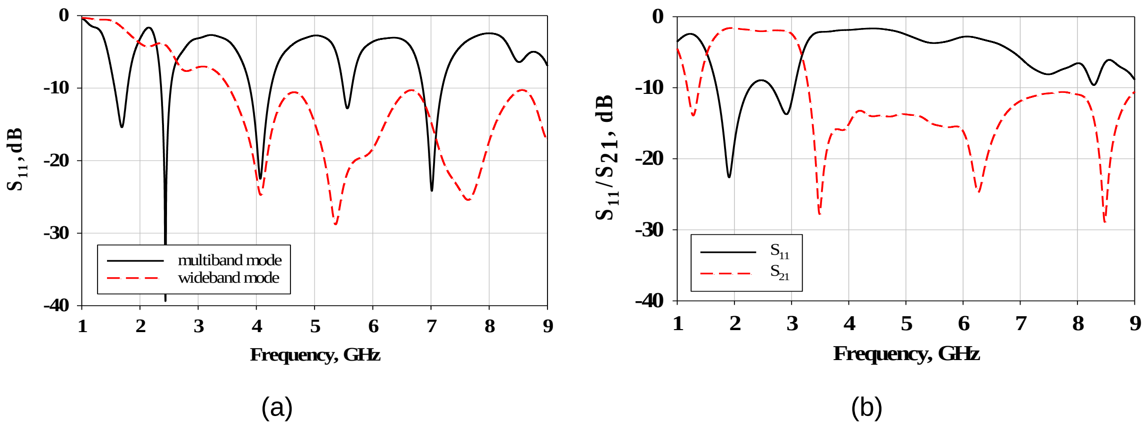


Figure 2. Simulated results of (a) S_{11} of antenna A (b) S11 and S_{21} of band-pass filter

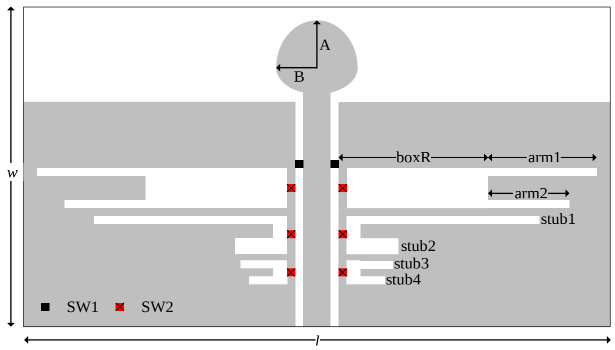


Figure 3. The proposed antenna B

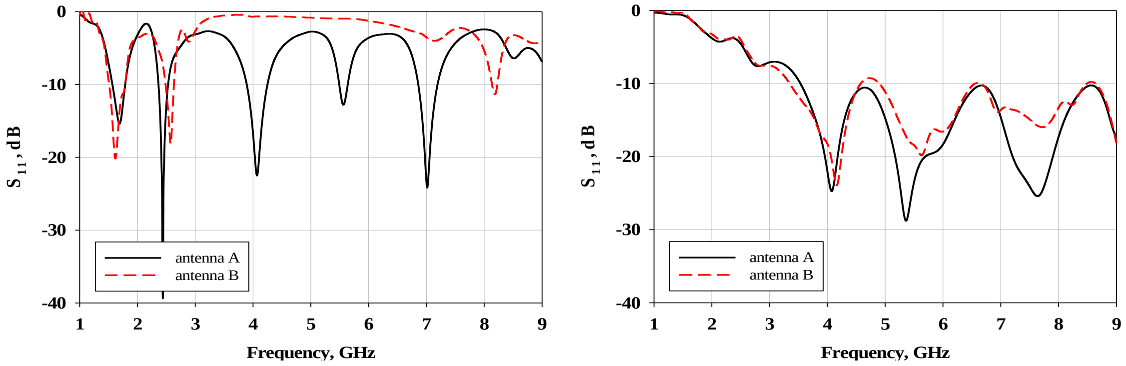
Table 1. Parameters of the Proposed Antenna B Structure

Parameter	Dimension (mm)	Parameter	Dimension (mm)
l	115	boxR	30
w	62	stub1	40
A	7	stub2	9
B	4	stub3	7
arm1	24	stub4	6
arm2	16		

3. Results and Analysis

Figure 4 shows the reflection coefficient (S_{11}) in the multiband and the wideband modes. In the multiband mode, harmonic frequencies of antenna B is completely eliminated from 3.0 GHz to 6.0 GHz as opposed to antenna A. In the wideband mode, it shows that the result of antenna B is almost similar to antenna A even after adding the filter. The proposed antenna is simulated results of S_{11} for multiband and wideband modes are shown in Figure 5. Dual-band is achieved at 1.6 GHz and 2.6 GHz with S_{11} value of -19.67 dB and -14.33 dB. The bandwidth of lower band (1.6 GHz) is 280 MHz, range from 1.51 GHz to 1.79 GHz. While upper band bandwidth of 140 MHz, which is ranging from 2.49 GHz to 2.63 GHz, is achieved. However, there is another unwanted harmonic appears at 8.2 GHz with S_{11} value of -11.00 dB. Such result may occur because of the S_{11} result of the band-pass filter is below -3 dB from 7 GHz until 9 GHz as shown in Figure 2 (b). Therefore, the filter does affect the proposed antenna result from 7 GHz to 9 GHz in the multiband mode. Further analysis of this problem will be explained in simulated gain result. It can be noticed in wideband mode that the antenna can operate well from 3.35 GHz to 9 GHz. Three peaks are noticeable with the value of S_{11} below than -9 dB, therefore it is acceptable to be counted as a wideband from 3.35 GHz to 9 GHz.

Simulated radiation pattern results are shown in Figure 6. The radiation patterns simulated at 1.6 GHz and 2.6 GHz in multiband mode while 3.5 GHz and 5.2 GHz in wideband mode. H-plane for both multiband and wideband mode show that the patterns are nearly omnidirectional over the operating frequencies. Bidirectional patterns are achived for both modes of E-plane. The radiation patterns are almost uniform through out the entire bands either in multiband or wideband mode. Radiation pattern at 5.2 GHz for wideband mode as shown in Figure 6 (d) is slightly different compared to others bands, but it has same radiation pattern with or without filter as shown in Figure 7 (d). Figure 7 shows simulated radiation pattern for multiband and wideband mode of antenna A. It can be noticed that the similar patterns are obtained at same frequency between Figure 6 and Figure 7.



(a) (b)

Figure 4. Simulated S_{11} results (a) multiband mode (b) wideband mode

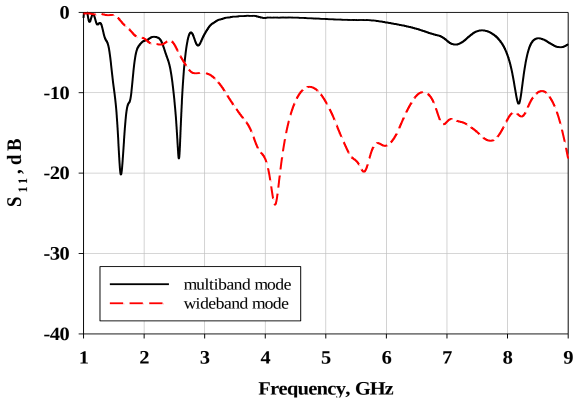
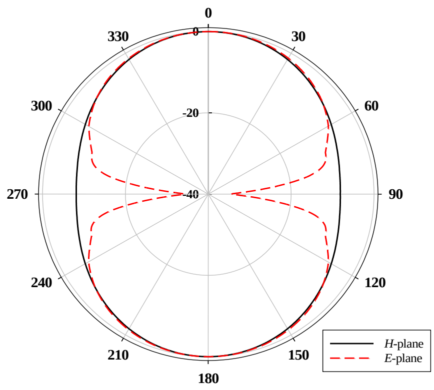


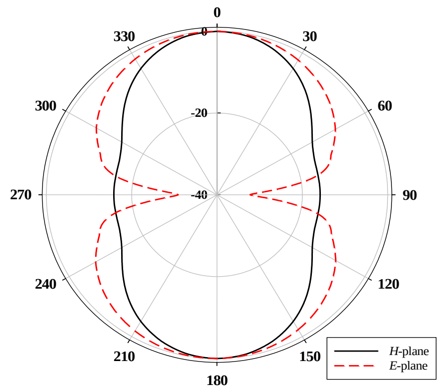
Figure 5. Simulated S_{11} results of the proposed antenna (antenna B)

Figure 8 (a) shows the antenna structure of wideband mode without the multiband resonator. Simulated radiation patterns of the antenna structure in Figure 8 (a) are shown in Figures 8 (b)-(c). Only radiation patterns results were shown here to show the consistency results of the radiation pattern in wideband mode between Figure 1 (a), Figure 3 and Figure 8 (a). From the figures, it can be noticed that radiation patterns from Figure 8 (b)-(c) are almost same with the patterns in Figure 6 (c)-(d) and Figure 7 (c)-(d). Consistency in the radiation pattern results are achieved; between the antenna structures in Figure 8 (a), Figure 1 (a) and Figure 3. Therefore, the radiation patterns are unchanged and followed the frequency reconfigurable antenna concept, where the radiation patterns remain unchanged even when the antenna is changed to different states or modes.

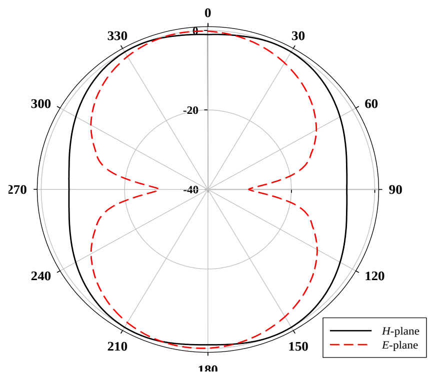
The simulated gain versus reflection coefficient results can be viewed in Figure 9. In multiband mode, maximum gain can be obtained at 1.6 GHz and 2.6 GHz, where the reflection coefficient (S_{11}) is below than -10 dB as expected. However, at 8.2 GHz (-11.0 dB), the maximum gain value of 0.32 dBi is obtained. In addition, higher gains which are 3.29 dBi and 2.64 dBi can be seen at 7.2 GHz and 8.7 GHz, respectively. But, the reflection coefficient value is only -3.9 dB at both of frequencies, 7.2 GHz and 8.7 GHz. In this case, only almost 60% power will be transmitted where 40% left will be reflected back to the source. Therefore, we are going to neglect the value because it will produce a lot of losses while transmitting the data. In Figure 9 (b), wideband gain result is higher than 2.1 dBi is recorded for the entire bands, from 3.5 GHz to 9.0 GHz. The maximum gain value of 5.54 dBi can be seen at 6.8 GHz. The overall result of gain for wideband mode is in good performance through out the frequency range from 3 GHz to 9 GHz. The summary of simulated gain results is tabulated in Table 2.



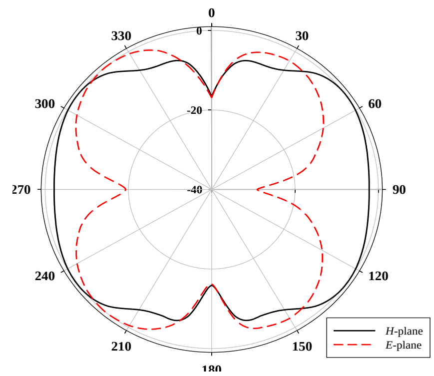
(a)



(b)

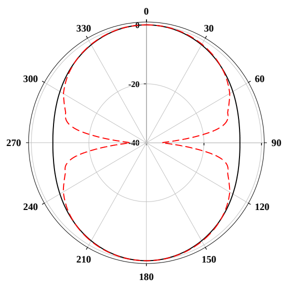


(c)

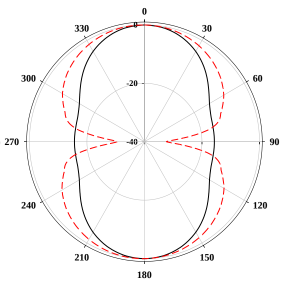


(d)

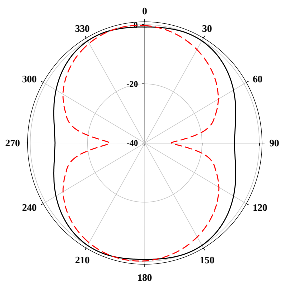
Figure 6. Simulated radiation pattern results of antenna B; in multiband mode at (a) 1.6 GHz (b) 2.6 GHz; in wideband mode at (c) 3.5 GHz (d) 5.2 GHz



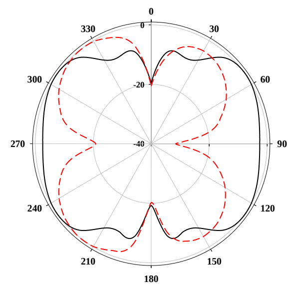
(a)



(b)



(c)

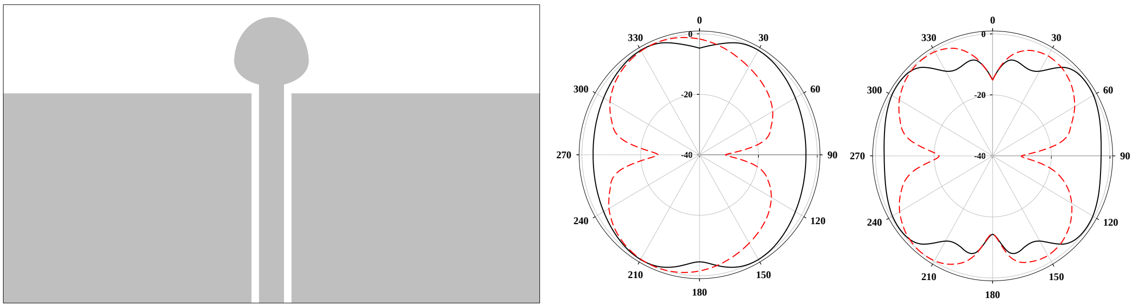


(d)

Figure 7. Simulated radiation pattern results of antenna A; in multiband mode at (a) 1.6 GHz (b) 2.6 GHz; in wideband mode at (c) 3.5 GHz (d) 5.2 GHz (solid line: H-plane, dashed line: E-plane)

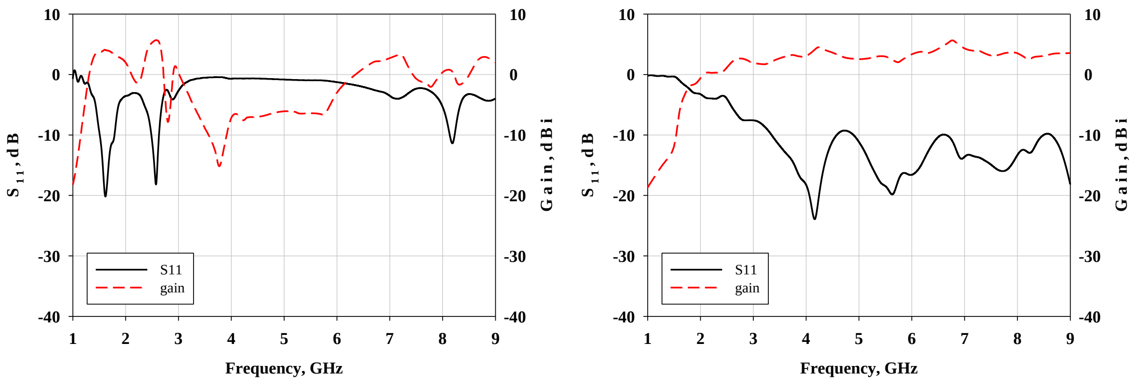
Table 2. Simulated Gain Results

Multiband mode		Wideband mode	
Frequency (GHz)	Gain (dBi)	Frequency (GHz)	Gain (dBi)
1.6	4.11	3.5	2.69
2.6	5.63	5.2	2.70



(a) (b) (c)

Figure 8. (a) Wideband antenna structure without multiband resonator; Simulated radiation pattern results in wideband mode at (b) 3.5 GHz (c) 5.2 GHz (solid line: H-plane, dashed line: E-plane)



(a) (b)

Figure 9. Simulated gain and S_{11} results (a) multiband mode (b) wideband mode

4. Conclusion

A reconfigurable antenna using ideal switches has been designed and simulated in this paper. Reconfigurability is achieved by switching ON or OFF four pairs of switches. Dual-band resonance of 1.6 GHz and 2.6 GHz is obtained in multiband mode while the wideband mode is ranging from 3.35 GHz to 9.0 GHz. Ideal switches will be replaced with real swiches such as pin-diode, which determine that this antenna can work in actual environment. The proposed antenna is suitable to be used in GPS, LTE and wideband wireless communication applications.

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