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Analysis of a dual-band phased array of switched-beam elements

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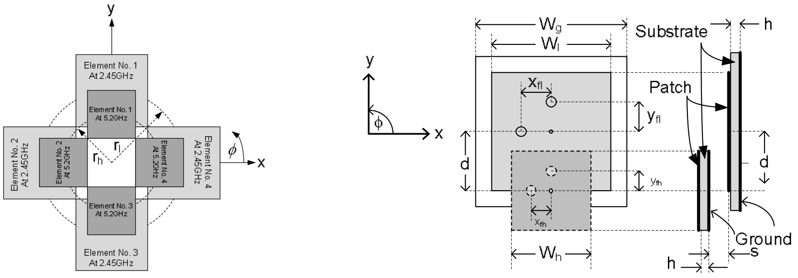
1. Introduction

With the demand of modern wireless communication technology, the requirement for a dual-frequency operation is increased for supporting multifunctional services, such as voice, video, and data transmissions. In particular, dual-band operation in 2.4/5.2 GHz band for wireless local area networks (WLANs) using only one antenna are desired. Practically, multipath fading and co-channel interference can seriously degrade the performance of the wireless communication system. The multipath fading is caused by the different path lengths with different arrival angle that arise from the transmitted signal impinging on object in the environment, while the co-channel interference is due to undesired co-channel signals from other base stations or user terminals. To overcome or reduce this problem, the switched-beam antenna can be an effective solution.

Dual-band antennas have been widely developed [1]-[3] but they have fixed radiation patterns. Tagapanij, *et al.,* [4] proposed a dual-band antenna that can switch the radiation pattern. It is a stacked-patch antenna that operates in a higher mode and has bidirectional patterns. The feeding probe can be selected by using an RF switch to change the radiation pattern. This paper presents the analysis of a dual-band phased array antenna at the frequency of 2.45/5.2 GHz that main beam can be switched by switching phase excitation and element patterns.

2. Antenna configuration

The configuration of a phased array of switched-beam elements is shown in Fig.1(a). It is designed to operate at the frequency of 2.45 and 5.2 GHz. A four-element circular array is formed with the array radius (r_h at high frequency and r_l at low frequency) by locating the switched-beam element No.1, No.2, No.3 and No.4 on the *xy*-plane at the position of ϕ=90°, 180°, 270° and 360°, respectively. To switch main beam of the array, the phase excitation of the n^{th} element (α_n) can be calculated as in [5].



(a) (b)

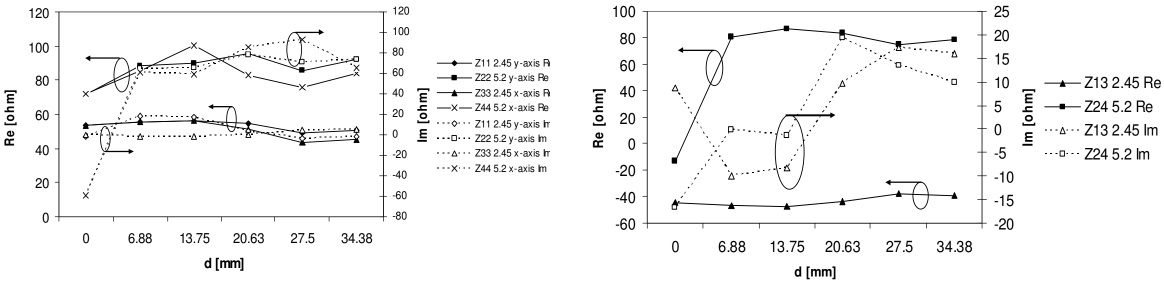
Figure 1: Configuration of a dual-band phased array antenna of switched-beam element
(a) Array configuration (b) Detail of each element

The analysis is focused on characteristics of a dual-band stacked-patch as shown in Fig.1(b). They are a square patch with width of each side of both frequencies are W_l and W_h at the frequency of 2.45 and 5.2 GHz, respectively. The patch height is *h* with dielectric constant of the substrate ε_r. It is located on *xy*-plane and is fed by a probe located on the *x* and *y* axes of the low and high frequencies at x_{fl}, y_{fl} and x_{fh}, y_{fh}, respectively. The high frequency antenna is stacked on the low frequency one with air separator (*s*). The antenna width along the *x* and *y* axes are one wavelength in dielectric substrate (λ_d). The electric field distribution is either TM_{020} or TM_{200} mode depending on the feeding probe position.

3. Simulation Results

3.1 Element of array

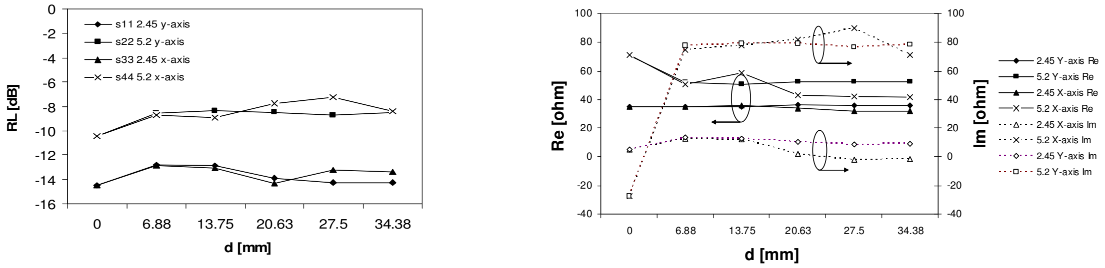
To investigate this antenna for operating at 2.45 GHz and 5.2 GHz, an FR-4 substrate with h, ε_r and loss tangent of 0.6525 mm, 4.36 and 0.012, respectively, was used. The patch width W_l and W_h were fixed to 58 mm and 27.5 mm, respectively. They correspond to the one wavelength in dielectric substrate at 2.45 and 5.2 GHz. The probe position was fixed to 19.5 mm and 5.88 mm from the center of the patch at the frequency of 2.45 and 5.2 GHz, respectively. Ground plane width W_g was fixed to 78 mm. All characteristics were investigated by varying distance d from 0 mm to 34.38 mm. The CST electromagnetic simulator [6] was used in simulation.



(a) (b)

Figure 2: Impedance versus d
(a) Self impedance (b) Mutual impedance

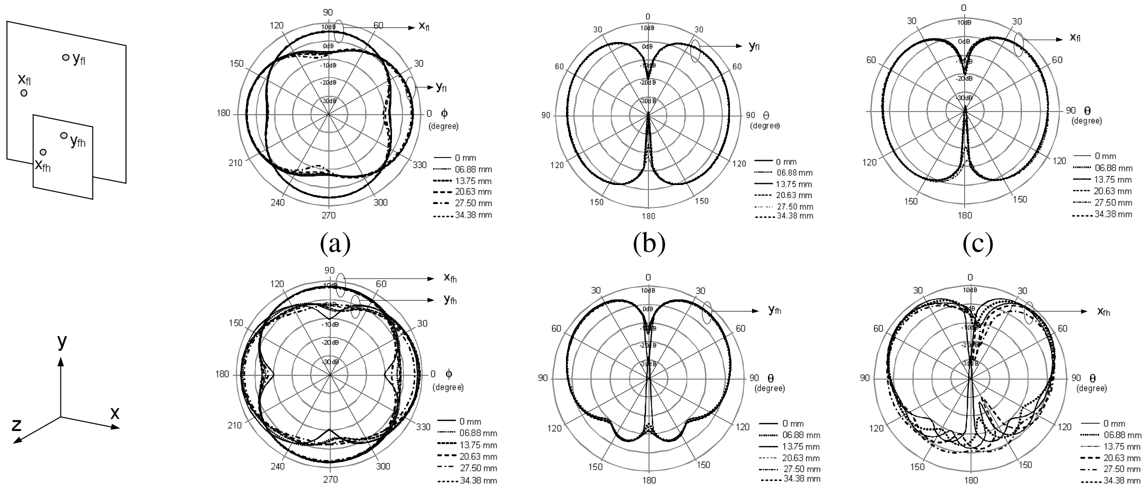
Impedance characteristics were investigated in term of self and mutual impedance versus d. Fig. 2 shows impedance characteristics in term of self and mutual impedance. At distance d = 0 mm, self impedance at the frequency of 2.45 and 5.2 GHz are 53-j1.9 Ω and 71-j58 Ω, respectively. When distance d is increased from 6.88 mm to 34.38 mm, variation is rather constant. At the same range, mutual resistance varies between x_{fl} and y_{fl} at 2.45 GHz, x_{fh}, y_{fh} at 5.2 GHz are about -40 Ω and 80 Ω, respectively. They are shown in Fig. 2(b). However, mutual reactance deviates between –j15 Ω to j20 Ω for both frequencies.



(a) (b)

Figure 3: Return loss and driving point impedance versus d
(a) Return loss (b) Driving point impedance

Fig. 3(a) illustrates return loss versus d at the frequency of 2.45 and 5.2 GHz. At d equals 0mm, return loss at 2.45 and 5.2 GHz are -14.47 dB and -10.46 dB, respectively. When distance d is increased, return loss at 2.45 GHz is lower than -12 dB all the range from 6.88 mm to 34.38 mm. On the other hand, it is higher than -9 dB at 5.2 GHz at the same range. Fig. 3(b) illustrates driving point impedance versus d are about 35+j10 Ω and 55+j75 Ω at the frequency of 2.45 and 5.2GHz, respectively. It is obvious that changing of the patch position at both frequencies influences mutual reactance as in Fig. 2(b). However, the only impedance characteristic is not sufficient to clarify the antenna characteristic.



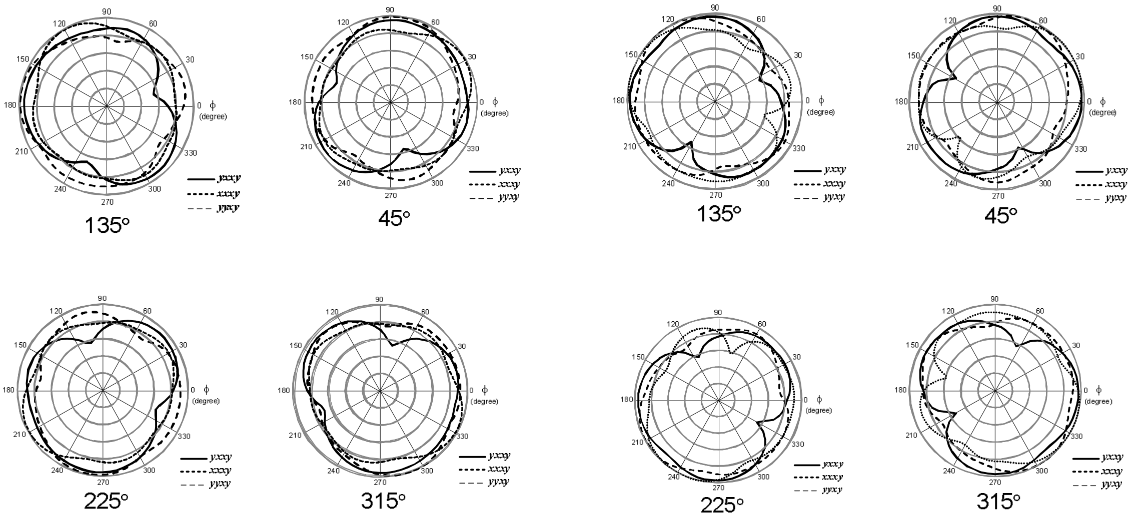
(a) (b) (c)

(d) (e) (f)

Figure 4: Radiation patterns
(a) 2.45 GHz on *xy*-plane at θ=45° (b) 2.45 GHz on *xz*-plane at ϕ=0°
(c) 2.45 GHz on *yz*-plane at ϕ=90° (d) 5.2 GHz on *xy*-plane at θ=45°
(e) 5.2 GHz on *xz*-plane at ϕ=0° (f) 5.2 GHz on *yz*-plane at ϕ=90°

Radiation patterns on azimuth (*xy*) and elevation (*xz* and *yz*) planes at the frequency of 2.45 and 5.2 GHz are shown in Fig. 4. It is observed that radiation patterns at the frequency of 2.45 GHz are same at all planes and all distance *d*. On the contrary, the radiation patterns at the frequency of 5.2 GHz are different. Particularly, at the elevation plane in Fig. 4(f), the main beam tilts down from θ = 40° to 55° when distance *d* is increased from 0 mm to 34.38 mm. The patch at the frequency of 2.45 GHz behaves as a reflector of the 5.2 GHz patch. As it is moved along distance *d*, the radiation patterns of the 5.2 GHz patch are non-symmetry. Nevertheless, the deviation of the radiation pattern is not considerable when considered on azimuth plane.

3.2 Array characteristics



(a) (b)

Figure 5: Array radiation patterns on *xz*-plane at θ=45°
(a) At the frequency of 2.45 GHz (b) At the frequency of 5.2 GHz

The proposed array consists of four elements arranged in circular configuration. The radius is an important parameter to determine front-to-back ratio, directivity, half-power beam width and beam shape. Actually, the proper radius is between $0.3\lambda_0 - 0.375\lambda_0$ at each frequency [5]. However, the array radius of the proposed array is $0.5\lambda_0$ to avoid overlapping of the element. Therefore, the appropriate beam shape is not obtained.

Fig. 5 shows array azimuthal radiation patterns at the frequency of 2.45 and 5.2 GHz on the elevation angle θ=45°. The radiation patterns at the frequency of 2.45 GHz can be switched to the angle of 45°, 135°, 225° and 315° by excitation with the elements as *yxxy*, *xxyy*, *xyyx* and *yyxx*, respectively. Meanwhile, radiation patterns at the frequency of 5.2 GHz can be switched to the angle of 45°, 135°, 225° and 315° by excitation with the *xyyx*, *yyxx*, *yxyx* and *xxyy*, respectively. The beam direction can be tuned to nearby angle by switching feeding probe positions. Due to the array radius are longer than $0.375\lambda_0$, front-to-back ratio, directivity, half-power beam width and beam shape cannot be controlled individually.

4. Conclusions

A dual-band phased array antenna was analyzed at the frequency of 2.45 GHz and 5.2 GHz. The results demonstrate that the impedance characteristics and radiation patterns are slightly influenced by increasing the distance d. It is possible to form an array. The antenna can switch the main beam to four directions at the angle of 45°, 135°, 225° and 315° for both frequencies by phase excitation. The patterns can be tuned to nearby angle by switching either x_f or y_f feeding probe of each element. In the future, back-lobe level will be decreased by decreasing the array radius. It is possible to arrange the array structure by locating the switched-beam element No.1, No.2, No.3 and No.4 on the xy-plane at the positions of ϕ=45°, 135°, 225° and 315°, respectively. With this solution, array radius can be decreased to less $0.375\lambda_0$. This dual-band phased array of switched-beam element can be applied to the Wireless Local Area Network (WLAN) system.

Acknowledgments

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