Switched Beam-forming Antenna with Reconfigurable Power Divider for WLAN System

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Abstract

This paper presents a switched beam-forming antenna with reconfigurable power divider for WLAN system. The proposed antenna consists of two folded dipole antennas which are placed perpendicularly, and generates three beam-patterns by reconfigurable divider. And, the antenna gains are 4.45 dBi, 4.21 dBi and 2.85 dBi in each radiation mode.
Keywords : Switched beam-forming antenna, Reconfigurable power divider

1. Introduction

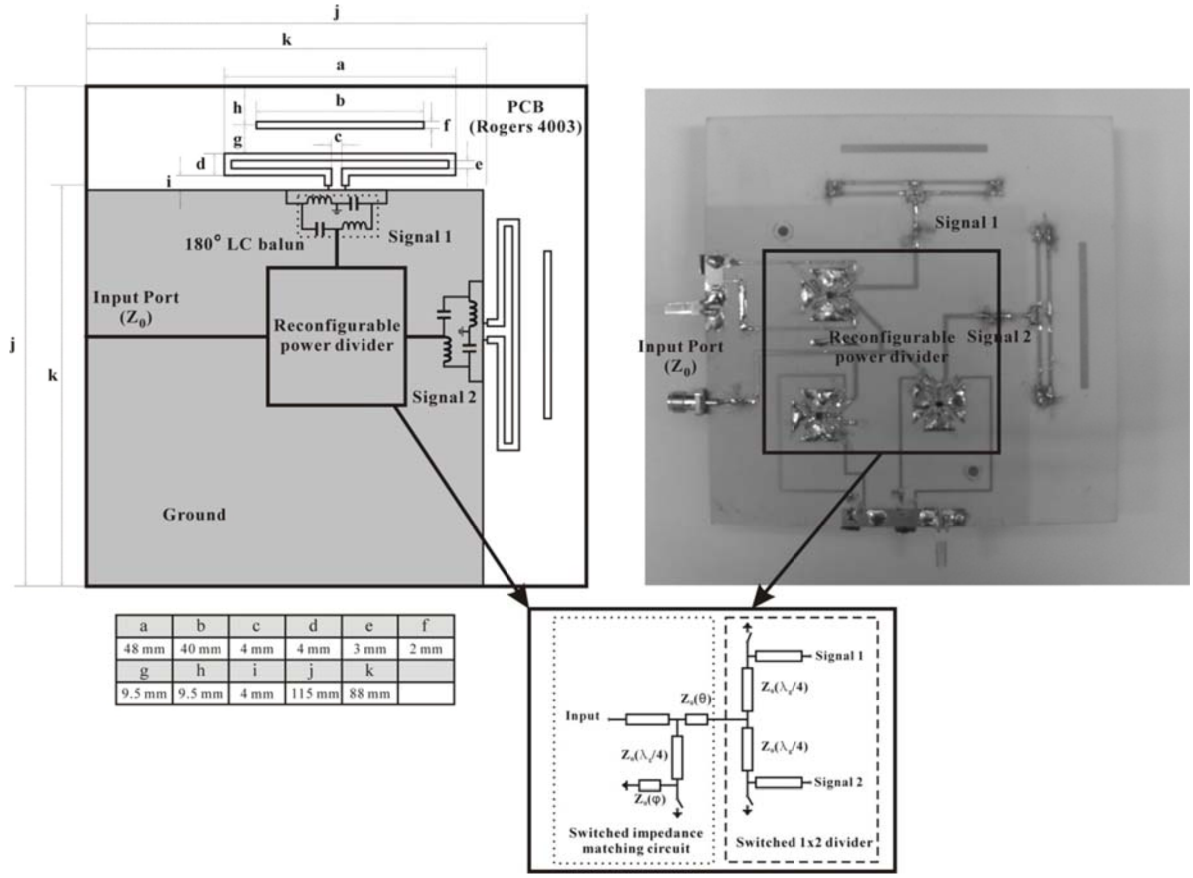
Beam-forming communications are required for implementing efficient communications for various environments in wireless communications. Therefore for decades, the beam-forming antennas have been researched and utilized in wireless communications applications, and recently the switched beam-forming systems which generate multi beam-pattern have drawn lots of attention in wireless communications due to excellent data transfer performance, such as WLAN, GPS and RFID [1]-[4]. In this paper, a new switched beam-forming antenna with reconfigurable power divider for WLAN system is presented. The proposed antenna is composed of two folded dipole antennas which are placed perpendicularly, and generates three beam-patterns by using reconfigurable divider. The reconfigurable power divider is composed of a switched divider and a switched impedance matching circuit. The switched divider consists of four λ/4 transformers and two switches to control the signal flow to outputs. Parallel switch structure is employed to minimize the insertion loss in the switched divider. Also, the switched impedance matching circuit consists of tuning stubs, λ/4 transformers and parallel switches to maintain the matching condition in the circuit. The proposed antenna is designed to operate at 2.45 GHz and has 3-radiation modes (vertical, horizontal and diagonal radiation mode). The antenna gain is 4.45 dBi, 4.21 dBi and 2.85 dBi in each radiation mode.

2. Antenna Design

Fig. 1 shows the structure and photograph of the proposed switched beam-forming antenna. The proposed structure is fabricated on a Rogers 4003C with a thickness of 0.508 mm, a relative dielectric constant (ε_r) of 3.38 and a loss tangent (δ) of 0.0023, and total circuit size is 115 mm × 115 mm. The proposed structure is composed of two folded dipole antennas and 1×2 reconfigurable power divider to generate three beam-patterns, vertical, horizontal and diagonal radiation pattern.

2.1 **Reconfigurable Power Divider Design**

The structure and simple block diagram of the proposed reconfigurable power divider is shown in Fig. 1. The proposed reconfigurable divider has three power transmission states (two 1:1 operation modes, and one 1:2 operation mode) and consists of a switched 1×2 divider and a switched impedance matching circuit. The switched 1×2 divider controls the signal path flow to the output and the switched impedance matching circuit maintains the matching condition. When the switch is off, the input signal is transmitted to the output with almost no reflection because the input



a	b	c	d	e	f
48 mm	40 mm	4 mm	4 mm	3 mm	2 mm
g	h	i	j	k	
9.5 mm	9.5 mm	4 mm	115 mm	88 mm	

Figure 1: The structure and photograph of the proposed switched beam-forming antenna.

impedance of the switch is nearly infinity. When the switch is on, the input signal is almost all reflected in the junction of the divider and is transmitted to other switch-off paths because the input impedance of the switch is nearly zero and the impedance from the junction into the output is nearly infinity due to the λ/4 transformers. Also, the impedance matching circuit compensates impedance mismatching in the junction of the divider by controlling the parallel switch on λ/4 transformer. For design of the switched impedance matching circuit, it is necessary to consider the conjugate matching condition between the input impedance of the switched divider and the impedance from the junction into switched matching circuit in each operation mode. Therefore, by the proposed matching condition, the parameter values of the proposed circuit are expanded to

$$\theta = \tan^{-1}\sqrt{\frac{Z_{s,off}^{2} + Z_0^{2}}{2Z_{s,off}^{2} + Z_0 Z_{s,off} - Z_0^{2}}},\ \ \varphi = \tan^{-1}\frac{Z_{s,off}(1-\tan^2\theta)}{(\tan\theta(Z_{s,off} + 2Z_0))}, \tag{1}$$

where, $Z_{s,off}$ is the input impedance of the switch when the switch is off. If the insertion loss of the switch is α, the input impedance of the switch is related by

$$Z_{s,off} = Z_0 \frac{1+10^{-\frac{\alpha}{10}}}{1-10^{-\frac{\alpha}{10}}}, \tag{2}$$

When α = 0.35 dB, the results, from Equations (1) - (2), are θ = 35.1° and φ = 33.8°. The calculated parameter values are used to design the proposed reconfigurable power divider.

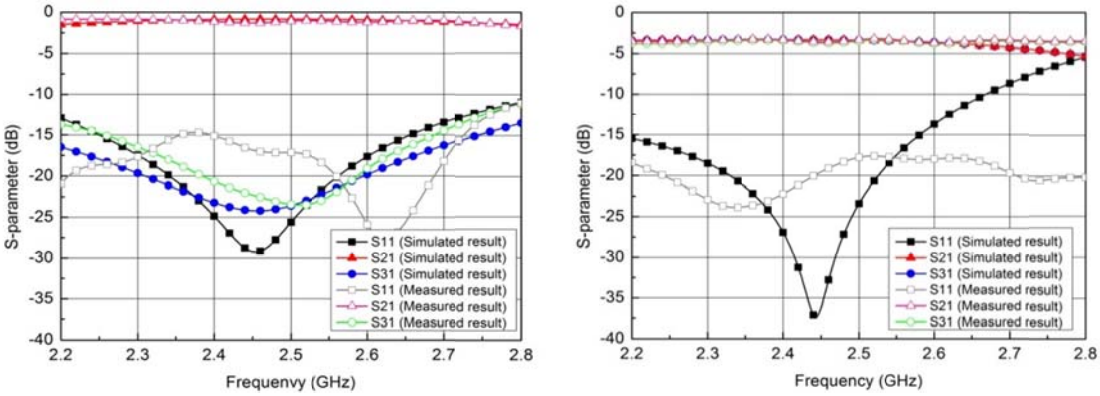
2.2 **Folded Dipole Antennas Design**

The structure of proposed folded dipole antenna is shown in Fig. 1. The proposed antenna is composed of two folded dipole antennas which are placed perpendicularly. Each folded dipole antenna has director (40 mm × 2 mm) and common ground (9.5 mm × 9.5 mm) for good antenna directivity. Also, the LC balun is used by differential and impedance transformer for the folded dipole antenna. The proposed antenna is designed by 3-D EM simulation tool (SEMCAD X by SPEAG, www.speag.com) and the parameter values of antenna are shown in Fig. 1.

3. Experiment Result

3.1 **Reconfigurable Power Divider**

To implement the proposed reconfigurable power divider, three NEC UPG- 2010TB single pole double throw (SPDT) switches with an insertion loss of 0.35 dB at 2.45 GHz are used. Fig. 2 shows the simulated and measured performance properties of the proposed circuit. The simulation was executed with a microwave CAD tool, using data for the UPG-2010TB model. Fig. 2 (a) shows the S-parameter of the proposed circuit in 1:1 operation mode. At the target frequency (2.45 GHz), the return loss (S11) is less than - 15 dB, the transmission coefficient and loss for on-path port (S21) are – 0.85 dB and 0.85 dB, and the isolation for the off-path port (S31) are greater than 20 dB. And, Fig. 2 (b) shows the S-parameter in 1:2 operation mode. At the target frequency, the return loss (S11) is less than - 20 dB, and the transmission coefficient and loss for on-path ports (S21 and S31) are – 3.45 dB and 0.45 dB.



(a) (b)

Figure 2: Performance of proposed reconfigurable power divider for each power transmission state. (a) 1:1 mode. (b) 1:2 mode.

3.2 **Switched Beam-forming Antenna**

Fig. 3 shows the measured return loss of the proposed antenna. The center frequency of proposed antenna is about 2.45 GHz and return loss at the center frequency is less than -20dB in each radiation modes. And, Fig. 4 shows the measured 3-D radiation pattern of the proposed antenna at 2.45 GHz. The antenna gain is 4.45 dBi in vertical radiation mode, 4.21 dBi in horizontal radiation mode and 2.85 dBi in diagonal radiation mode. The proposed switched beam-forming antenna generates three beam-patterns by controlling the switches in reconfigurable power divider.

4. Conclusion

In this paper, a new switched beam-forming antenna with reconfigurable power divider for WLAN system has been presented and verified. The proposed antenna is expected to be researched and utilized in many wireless communications application due to multi beam-pattern characteristics, and is expandable into a 1×N structure with proper arrangement of antennas and design of reconfigurable power divider.

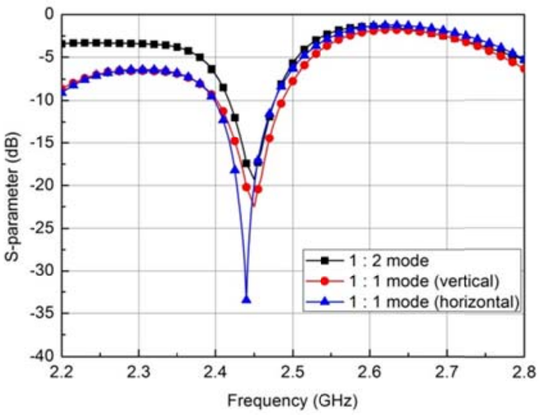
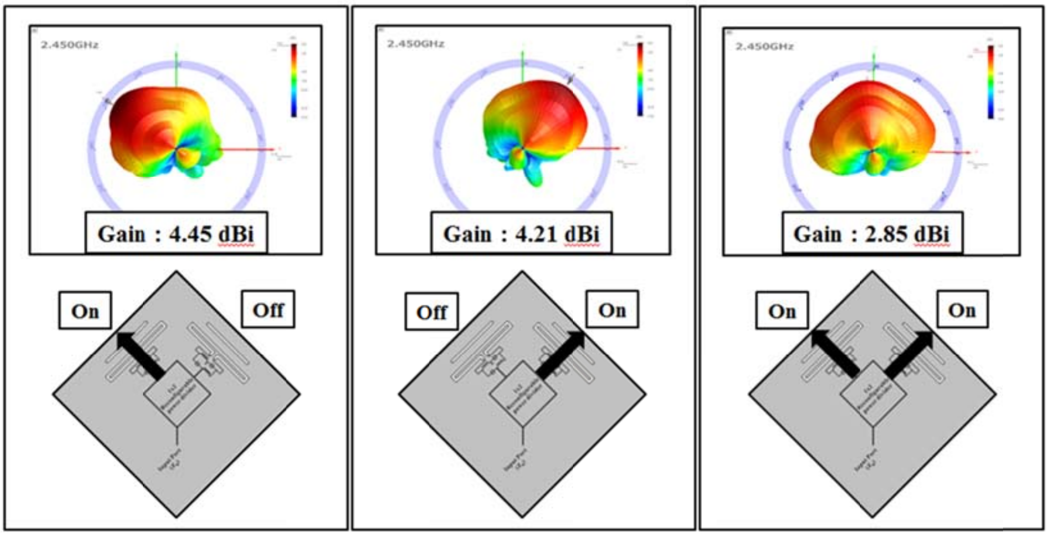


Figure 3: Measured return loss of the proposed antenna



(a) (b) (c)

Figure 4: Measured 3-D radiation pattern of the proposed antenna at 2.45 GHz (a) Vertical radiation mode. (b) Horizontal radiation mode. (c) Diagonal radiation mode

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Acknowledgments

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