Frequency reconfigurable bow-tie antenna array

Tong Li, Huiqing Zhai and Chang-Hong Liang

A novel frequency reconfigurable bow-tie antenna array for Bluetooth, worldwide interoperability for microwave access (WiMAX) and wireless local area network (WLAN) applications is presented. This array comprises four double-sided bow-tie elements and an ultra-wideband feed network. By controlling the states of the *pin* diodes loaded on the radiators, the effective electrical lengths of bow-tie elements can be changed, thus the operating band of the array can be electronically switched between three different frequency bands. A prototype was fabricated and measured, and the results are in good agreement with the simulations, which shows that this array is a good candidate for multi-radio wireless applications.

Introduction: Modern wireless communication systems require antennas to operate at different wireless frequency bands. Therefore, the frequency reconfigurable antenna has gained significant attention recently [1–3]. Compared to the conventional wideband and multiband antennas, the frequency reconfigurable antenna can adjust its operating band according to the need in varying radio environments, thus avoiding interference from the bands that are not in use. Lately, a number of frequency reconfigurable antennas have been reported. In [2], a reconfigurable rectangular slot ring antenna is proposed. However, the antenna can only be switched to operate in two frequency bands. Tariq and Shiraz [3] presented a frequency reconfigurable monopole antenna using *pin* diodes to achieve several operating bands. However, the DC biasing circuit contains lots of bias lines and lump elements that affect the antenna performance and make the structure more complex as well. For systems requiring high antenna gains, it is more desirable to design a frequency reconfigurable antenna array. In [4], a reconfigurable log periodic patch array was designed. However, the reconfigurability was realised by ideal open and closed circuits instead of real switches, and the DC biasing circuit needs to be further investigated.

In this Letter, a novel frequency reconfigurable bow-tie antenna array is proposed for the first time. This array consists of four double-sided bow-tie antennas and an ultra-wideband feed network. By loading *pin* diodes on the bow-tie arms, the operating band of the array can be electronically switched between Bluetooth, worldwide interoperability for microwave access (WiMAX) and wireless local area network (WLAN) bands. Moreover, the simple and effective biasing circuit proposed in this Letter contains only two bias lines and can be placed far away from the radiators, thus greatly reducing the effect on antenna performance.

Antenna design and discussion: The configuration and dimensions of the proposed reconfigurable bow-tie antenna array are shown in Fig. 1*a*. The array comprises 2×2 bow-tie elements and an ultra-wideband feed network. The feed network includes a microstrip-to-parallel strip transition, T-junction power dividers and tapered impedance transformers. The horizontal and vertical spacings between the elements are chosen to be 70 and 32 mm, respectively. To avoid grating lobes, the vertical spacing needs to be smaller than the horizontal one because the antenna's radiation pattern is omnidirectional on the elevation plane.

Fig. 1*b* shows the configuration of one bow-tie element. Parts of the triangular radiator are cut to achieve a more compact size. To realise reconfigurability, six *pin* diodes are symmetrically loaded on the bow-tie arms. Note that two narrow strips with metallic vias are added to the radiator to connect its symmetric parts; thus the antenna only needs one pair of bias lines to bias all the diodes. The inductors $Ls1$ and $Ls2$ of 20 nH are used to isolate RF signals while maintaining DC connection; thus the presence of the strips almost has no effect on the antenna's performance. The elimination of extra bias lines avoids distortion of the radiation pattern. To isolate the RF source from the DC current, a 10 pF capacitor C_R is mounted over the microstrip feedline. Two lowpass filters comprising 20 nH RF-choke inductors L and 15 pF DC-blocking capacitors C are integrated in the array to isolate DC from RF signals. A 100 Ω current-limiting resistor R is also used in the circuit [5].

Note from Fig. 1*b* that the diodes have different orientations and they can be classified into two groups. Group A contains $S1$, $S1'$ and $S4$ and Group B contains the others. When no DC voltage is applied, all the diodes are in OFF-state; thus only the inner triangular parts radiate, as shown in Fig. 2*a*. The array now operates at 5.5 GHz. When a forward DC voltage is applied, diodes in Group A are turned on and the middle parts of the radiators are activated (Fig. 2*b*). Now the array operates at 3.5 GHz. Changing the polarity of the DC voltage makes the diodes in Group A OFF and diodes in Group B ON. Now the whole radiators are active (Fig. 2*c*) and the array operates at 2.4 GHz.

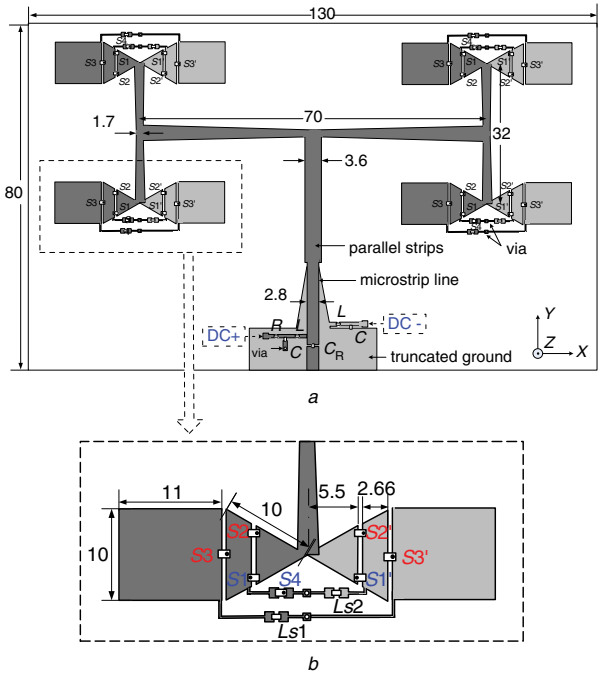

Fig. 1 *Configuration of reconfigurable bow-tie antenna array and zoomed-in view of one bow-tie element*

a Reconfigurable bow-tie antenna
b One bow-tie element

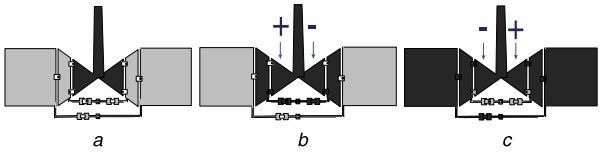

Fig. 2 *Different operating states*

a No voltage applied (state 1:5.5 GHz)
b Forward voltage applied (state 2:3.5 GHz)
c Reversed voltage applied (state 3:2.4 GHz)

Fig. 3 *Fabricated reconfigurable antenna array*

a Top view
b Bottom view

Simulated and measured results: The proposed array was printed on a dielectric substrate of relative permittivity $\varepsilon_r = 2.65$ and thickness $h =$ 1 mm, as shown in Fig. 3. The *pin* diodes used in our design were Infineon BAR50-02V. The diode was modelled as a 3 Ω resistor at ON-state and a 0.15 pF capacitor in parallel with a 5 kΩ resistor at OFF-state in the high-frequency structure simulator simulations. The simulated and measured reflection coefficients are shown in Fig. 4. As can be seen, the measured operating bands of the three states are 2.27–2.68, 3.25–3.92 and 4.14–6 GHz, respectively, successfully covering Bluetooth, WiMAX and WLAN bands. The radiation patterns and

peak gains of the proposed array at 2.4, 3.5 and 5.5 GHz were measured in an anechoic chamber. The results are shown in Fig. 5 and Table 1. As the frequency increases, the beamwidths on *E*- and *H*-planes become narrower due to the enlarged effective electrical lengths of the radiators.

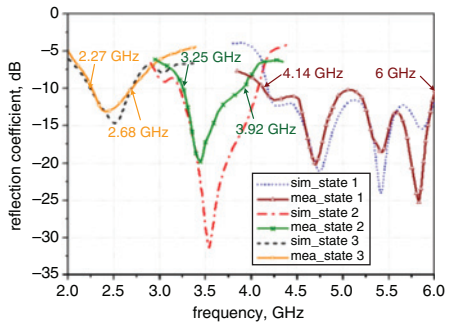

Fig. 4 *Simulated and measured reflection coefficient for different diodes states*

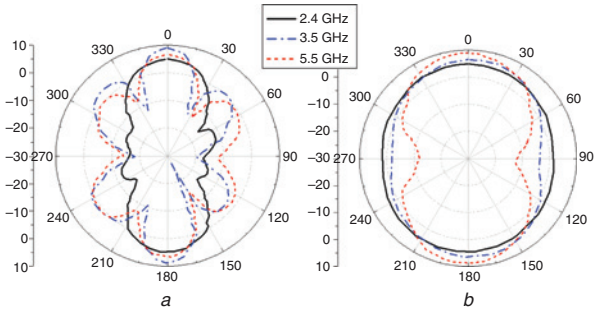

Fig. 5 *Measured radiation patterns*
a *E*-plane
b *H*-plane

Table 1: Peak gain of proposed array

Frequency (GHz)	2.4	3.5	5.5
Gain (dBi)	4.37	6.1	9.8

Conclusion: A novel frequency reconfigurable bow-tie antenna array is presented. By controlling the states of the *pin* diodes loaded on the radiators, the operating band of the array can be electronically switched between Bluetooth, WiMAX and WLAN bands. The simulated results are confirmed by the experiments and good agreements are observed, which show that this array is a good candidate for multi-radio wireless applications.

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One or more of the Figures in this Letter are available in colour online.

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