Back-to-Back Microstrip Antenna Fed with Tunable Power Divider

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***Abstract*—A microstrip antenna structure with pattern reconfigurable characteristics is described. The structure consists of two stacked patch antennas and a tunable feeding network. The two antennas are arranged by a back-to-back configuration, and they are respectively excited by the outputs of the 1-to-2 feeding network composed of a quasi-lumped coupler and two varactor diodes. With controlling the dc voltage of the varactors, the ratio of two outputs of the feeding network can be varied between 1 and 13 dB so that the radiation pattern generated by the two antennas is changed. A prototype operating at 2.45 GHz band is implemented and tested. Experimental results demonstrate that the radiation of the prototype in the H plane can be switched among omnidirection pattern and broadside patterns with various front-to-back ratios.**

***Index Terms*—microstrip antenna, tunable power divider, pattern reconfigurable**

I. INTRODUCTION

Monopole and microstrip antennas with moderate gains are often applied into indoor base stations of WLANs. In addition to the monopole antennas, the omnidirectional radiation pattern can be generated from the microstrip antennas. For example, a square patch antenna operated at the wire-patch mode [1] or a circular patch antenna operated at TM_{01} mode [2]. The two antennas have uniform radiation fields across all azimuthal angles (ϕ), but their peak gains occur at a specific elevation angle (θ). Such a conical radiation pattern is only suitable for the base station mounted on ceilings. A dipole-like radiation pattern is more practical, and it can be realized using back-to-back microstrip antennas [3], in which both antennas are operated at the fundamental mode and they are excited with the same amplitude. Based on the back-to-back microstrip configuration, it can be expected that the radiation is omnidirectional as the two antennas are evenly excited, and it turns into unidirectional when only one antenna is activated. Furthermore, if the two antennas are excited with different amplitudes, broadside radiation patterns with various front-to-back ratios would be obtained. To achieve such a pattern switching, a tunable feeding network is required. Therefore, a 1-to-2 feeding network is first proposed in this paper. The feeding network is composed of a quasi-lumped coupler and a pair of varactors, and the ratio of its two outputs can be tuned. Then, a dual-feed back-to-back microstrip antenna is designed and excited with the proposed feeding network. Details of the designs and the measured results for the constructed prototypes are shown.

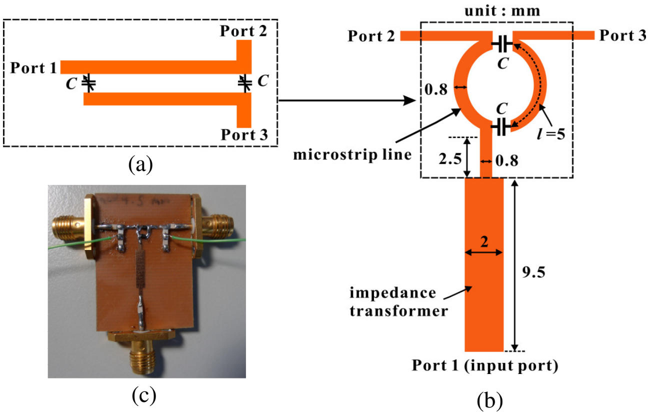


Fig. 1 (a) QLQC circuit (b) layout of the tunable power divider (c) photograph of the completed prototype

II. TUNABLE FEEDING NETWORK DESIGN

The proposed feeding network is developed from the quasi-lumped quadrature coupler (QLQC), shown in Fig. 1(a), that has two different working modes at the same operation band [4]. When C is sufficiently small, the QLQC operates at the uncoupled mode, and the output of Port 2 is much larger than that of Port 3. On the other hand, when C is large enough, the QLQC operates at the T-junction power divider mode, and the two outputs are the same. As a consequence, the QLQC can be considered as a tunable power divider at a specific frequency range, and the ratio, R, of the two outputs may be tuned by varying C. To prove the idea, an example was designed on a FR4 substrate of thickness 0.4 mm, and its layout is depicted in Fig. 1(b) along with the related dimensions. For various C, the simulated S parameters of the example are presented in Fig. 2. Note that the cases of $C = 15$ and 0.3 pF are corresponding to the T-junction power divider mode the uncoupled mode, respectively. Moreover, as C is reduced from 15 to 0.3 pF, the amplitudes of S_{21} and S_{31} are respectively heightened and lowered, implying that R is increased with a decrease of C. For making the outputs of the example can be tuned electrically, a pair of varactor diodes (SMV2019-079LF) are used instead of the capacitors C. A reversed dc bias (V_R) is required for controlling the varactors, and a low-pass filter with $L = 150$ nH and $C = 200$ pF serves as a RF choke. Fig. 1(c) shows the photograph of the completed prototype (Circuit Prototype). For the prototype, the variations of R at 2.45 GHz for different V_R are presented in Fig. 3, and the measured results illustrate that R can be tuned between 0 and 13 dB by controlling V_R.

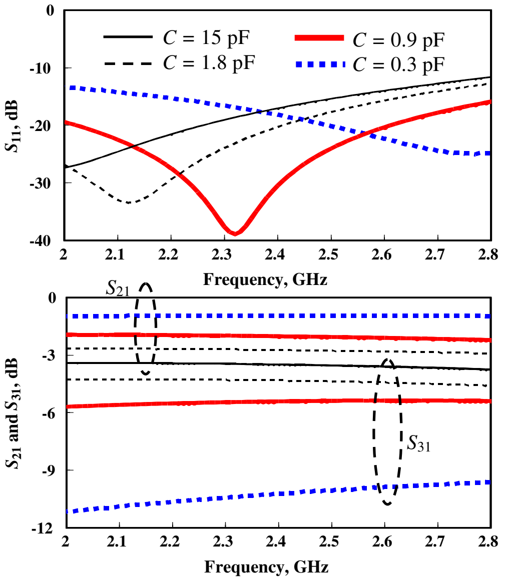


Fig. 2 Simulated *S* parameters of the tunable power divider

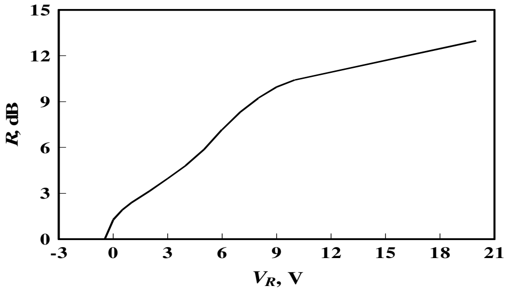


Fig. 3 Variations of *R* measured at 2.45 GHz against V_R

III. RECONFIGURABLE ANTENNA DESIGN AND RESULTS

Fig. 4 depicts the structure of a back-to-back microstrip antenna, in which the two antenna elements are fed with coplanar microstrip lines and both are operated at TM_{10} mode. A prototype (Antenna Prototype) was implemented according the dimensions revealed in Fig. 4. When Port A is activated and Port B is connected to a 50 Ω load, the results measured at 2.45 GHz indicate that the prototype has the broadside radiations with a peak gain of 6 dBi, a cross polarization level of -20 dB, and a front-to-back ratio of 13 dB. A pattern reconfigurable antenna is carried out by connecting Port 1 and Port 2 of Circuit Prototype to Port A and Port B of Antenna Prototype, respectively. A pair of low-loss coaxial cables with a length of 75 mm are used as the connection lines. For cases of V_R = -0.5, 2, 6.5, and 20 V, the return-loss results of the reconfigurable antenna, measured at the input port of Circuit Prototype, is presented in Fig. 5 (a), and they demonstrate that as V_R is changed, the antenna has acceptable impedance matching between 2.4 and 2.5 GHz. The radiation patterns of the four cases tested at 2.45 GHz are given in Fig. 5 (b), and the results prove that the radiation pattern can be reconfigured by controlling V_R. For the case of V_R = -0.5 V, an omnidirectional radiation pattern in *y*-*z* plane is obtained and the gain is about 1 dBi; however, the antenna radiation turns into a broadside pattern with a peak gain of 4.5 dBi and a front-to-back ratio of 13 dB when V_R is set to be 20 V. Furthermore, the peak gain and front-to-back ratio can be respectively altered from 1 to 4.5 dBi and from 0 to 13 dB by increasing V_R from -0.5 to 20 V. It has to be mentioned that the measured peak gain includes the feeding network loss and the cable loss.

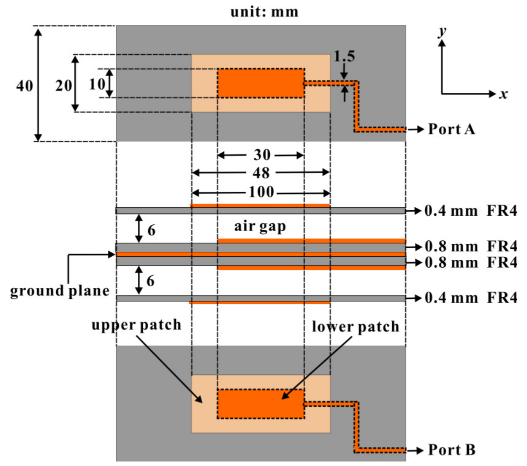
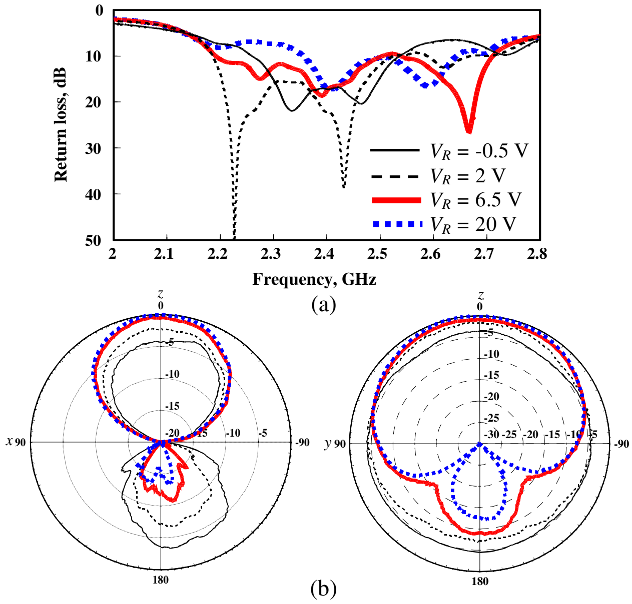


Fig. 4 Back-to-back microstrip antenna configuration



(a)

(b)

Fig. 5 Measured return loss and Co-pol radiation patterns for the reconfigurable antenna with various V_R

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