Pattern Reconfigurable Slot Antenna with Broadband Operation

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Abstract—**A pattern reconfigurable design using a single-feed slot antenna is presented. Several PIN diodes are embedded into the ground plane, and by controlling the states of the diodes, the antenna structure can be worked as a 0.5 λ slot antenna and a 0.75 λ monopole slot antenna. A prototype is designed to give three different radiation modes in the H-plane, and these modes can respectively generate an omnidirectional pattern and two unidirectional patterns with reversed main-beam directions. Experimental results indicate that the omnidirectional mode has a gain variation of about 6 dB across all azimuthal angles and the unidirectional mode has a front-to-back ratio of higher than 10 dB. In addition, the working bandwidth of the reconfigurable antenna is more than 15 %.**

Index Terms—**pattern reconfigurable antenna, slot antenna**

I. INTRODUCTION

Pattern reconfigurable antennas are attractive for present wireless communication systems, such as WLAN and sensor network systems, because they can provide a large coverage for transmitted signals and reduce the interference of undesired signals coming from known directions. The pattern switching can be achieved in a single antenna without any phase shifter, and a considerable number of the related designs have been proposed over the past years [1]-[5]. For these reported articles, two design methods are often employed. One is based on an antenna with multi-feed mechanisms [1],[2], and the pattern switching is realized by selecting one of the antenna feeds as the signal input port. For example, the feed points of the TM_{01} and TM_{11} modes of a circular microstrip patch antenna are respectively located at the center and off-center of the radiation patch, and consequently the radiation pattern of the antenna is either broadside or conical, depending on which feed point is activated [1]. Ref [2] exhibited another design where a star-shaped patch antenna is used and it can give four tilted beams by switching the feed points respectively located at the corners of the patch.

The other method is based on a single-feed antenna, and the antenna operation mode can be varied through controlling the states of the PIN diodes which need to be properly placed in the antenna structure. An example is given in [3] where the operation of a microstrip patch antenna is switched between the fundamental mode and a monopolar mode. A planar antenna structure that can be worked as a monopole antenna and a dipole antenna with a reflector was presented in [4]. Also, a novel antenna structure that can support a top-loaded monopole mode and a half-wavelength slot mode was reported in [5]. For these
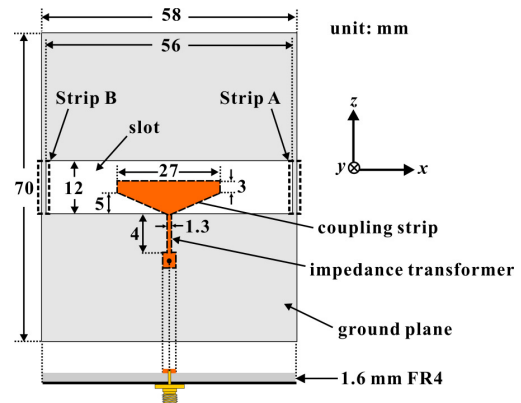

Fig. 1 Geometry of the studied antenna.

pattern reconfigurable designs using different operation modes, most of them only can perform the switching between broadside and conical radiations, namely the pattern switching in the θ plane, within a bandwidth of less 5 %, which seems to be unsatisfactory for the applications of present wireless communication systems. In this paper, a pattern reconfigurable design based on a single-feed slot antenna is proposed. The antenna can be operated at a traditional slot mode or a monopole slot mode, and the two modes have different radiation patterns in the H-plane (ϕ plane). In addition, the pattern switching can be well performed in a bandwidth of larger than 15 %.

II. ANTENNA STRUCTURES AND ANALYSES

Fig. 1 depicts the structure of a rectangular slot antenna fabricated on a FR4 substrate of relative permittivity 4.4. The antenna is excited with a feed line composed of an impedance transformer and a coupling strip. According to the dimensions in Fig. 1, the antenna is simulated using HFSS and the obtained return-loss results are shown in Fig. 2, where a minimum return loss is found at 2.1 GHz that is the resonant frequency of the half-wavelength slot antenna. When one edge of the rectangular slot is open by removing Strip A, the slot turns into a slit. The resultant structure can be considered as a monopole slot antenna, and its simulated return loss is also exhibited in Fig. 2. From the results, it is found that the antenna has a minimum return loss at 2.44 GHz which is corresponding to the resonant frequency of the 0.75 λ monopole slot antenna. It is interesting to note that the slot antenna and monopole slot antenna have the same dimensions except for Strip A, and their impedance bandwidths, determined by 10 dB return loss, have an overlap from 2.12 to
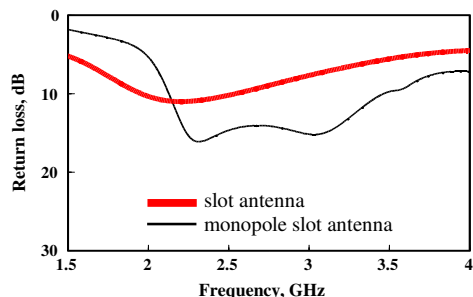
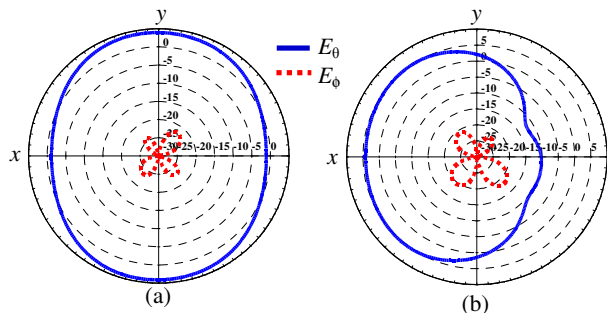Fig. 2 Simulated return loss of the slot and monopole slot antennas.

Fig. 3 Simulated radiation patterns of the slot and monopole slot
antennas.　(a) slot antenna　　(b) monopole slot antenna
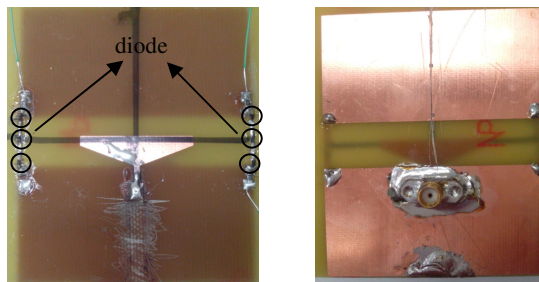

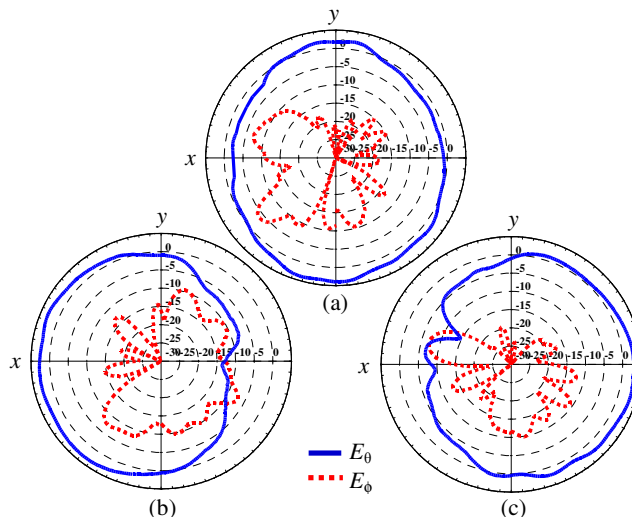Fig. 4 Photographs of the completed prototype.

Fig. 5 Measured radiation patterns of the prototype at three modes
(a) Mode A　　(b) Mode B　　(c) Mode C

Fig. 6 Measured return loss of Mode A, Mode B, and Mode C.

2.55 GHz. For the two antennas, their H-plane radiation patterns simulated at 2.45 GHz are plotted in Fig. 3, and the results indicate that the slot antenna has a nearly omnidirectional pattern but the monopole slot antenna radiates a unidirectional pattern toward +x axis. It can be expected that the unidirectional pattern is toward -x axis direction if Strip B of the slot antenna is removed instead of Strip A.

III.　RECONFIGURABLE ANTENNA DESIGN AND RESULTS

According to the above analyses, a pattern reconfigurable antenna is developed, and the photographs of the completed prototype are exhibited in Fig. 4. Three PIN diodes are evenly embedded on Strip A and the other three are on Strip B. As all of diodes are ON, the antenna operates at the half-wavelength slot mode. On the other hand, the antenna is the 0.75 λ monopole slot when the diodes on Strip A (Strip B) are ON and the diodes on Strip B (Strip A) are OFF. As a consequence, the prototype can provide three corresponding radiation modes in the H-plane, including omnidirectional mode (Mode A), unidirectional mode of $\phi = 0°$ (Mode B), and unidirectional mode of $\phi = 180°$ (Mode C). The radiation patterns of the three different modes are stable between 2.3 and 2.7 GHz. Typical results in the H-plane, measured at 2.45 GHz, are plotted in Fig. 5, and they demonstrate that Mode A has a peak gain of 3.5 dBi at $\phi = -90°$ and the gain variation is less than 6 dB across all azimuthal angles. As for Mode B and Mode C, their peak gains, respectively at $\phi = 0°$ and $\phi = 180°$, are around 3.2 dBi; moreover, the front-to-back ratio, determined by the magnitude of $E_\phi (\phi = 0°)_{dB} - E_\phi (\phi = 180°)_{dB}$, is higher than 10 dB. Fig. 6 also gives the measured return loss as the prototype operates at different modes. From the results, it is found that the pattern bandwidth, from 2.3 to 2.7 GHz, is located within the overlap
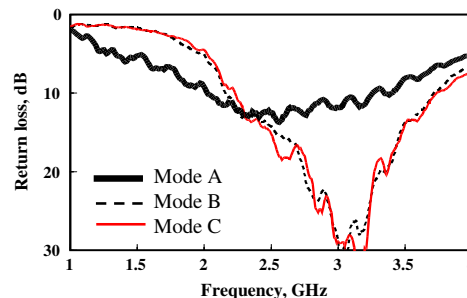
among the 10dB-return-loss bandwidths of the three modes. Therefore, the pattern reconfigurable antenna has a working bandwidth of 16 %.

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