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A Pattern Reconfigurable Slot Antenna with Hybrid Feed

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Abstract— In this paper we investigate the design and operating principle of a pattern reconfigurable multi-mode slot antenna with a hybrid feed. The slot antenna is excited by an orthogonal arrangement of a co-planar waveguide (CPW) fed circular disc and a microstrip fed square patch. The design objective is to be able to change the direction of the main lobe by feeding the two orthogonal elements with different phases.

I. INTRODUCTION

Antennas which have the ability to alter aspects of their performance, like shifting frequencies, bandwidth, gain or polarization have received significant attention recently [1]. These are attractive antennas for communications because they enable interference mitigation in changing environments.

The reconfiguration of the radiation patterns is typically done by steering the beam in one plane only [2, 3].

In this paper we investigate a pattern reconfigurable antenna with the ability to change the direction of the main lobe of the radiation pattern between the two elevation planes.

II. ANTENNA DESIGN

The antenna structure comprises two metallic layers on a dielectric substrate. The radiating element is driven by an arrangement of a CPW fed disc on one side and an orthogonal microstrip-fed square patch on the other side. The antenna geometry is shown in Figure 1 with both elements fed independently from the edge of the board. The dimensions of the substrate are 100 mm × 100 mm. On the lower side of the substrate, a square slot of 50 mm × 50 mm is excited by a circular disc at the coplanar waveguide. On the top side a square patch of 42 mm × 42 mm is fed by a microstrip line. The square patch and its feedline use the groundplane of the slot on the opposite side.

The radiating structure is the slot [4] between the groundplane and the square patch. The prototypes of this slot-hybrid antenna were fabricated on double-sided FR4 material of 1.52 mm thickness and dielectric constant of $\epsilon_r=4.3$.

The slot antenna is excited by an orthogonal arrangement of higher order modes [5], which realise a conical beam pattern with a main lobe $\theta=45^\circ$ from zenith. As the impedance of the higher order mode is lower, the multi port arrangement of the CPW disc and microstrip patch feeds can simultaneously excite the higher order modes of the slot.

When these orthogonal modes are excited with a relative phase difference of 90° or 270° the main lobe of the resulting farfield radiation pattern extends in the $\phi=90^\circ$ or $\phi=0^\circ$ elevation plane respectively.

In the first prototype (as shown in Figure 1), the two elements are fed through individual SMA connectors using external power splitter and phase shifter. This arrangement was used to verify the phase delay used to switch the pattern before implementing these phase delays with different lengths of feedline.

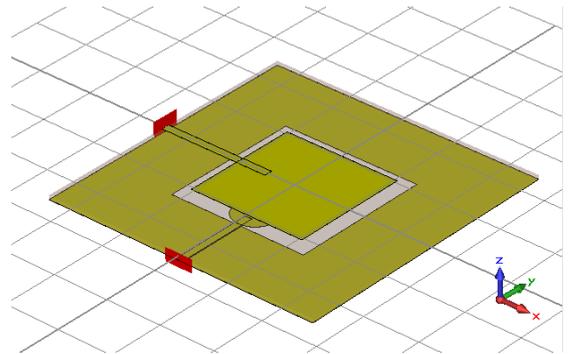


Fig. 1: Antenna with independently fed elements.

The simulated return loss for the individually fed elements is shown in Figure 2. Both elements are well matched at the operating frequency of 3.1 GHz with a return loss better than -17 dB.

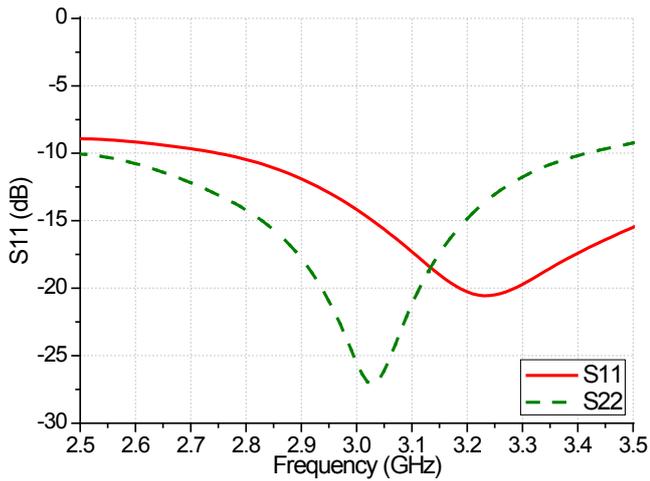


Fig. 2: Return loss of the antenna with individually fed elements.

The radiation pattern for the individually fed antenna is shown in Figure 3 and 4 for a phase shift at the microstrip fed patch of 90° and 270° respectively. It can be seen that the direction of the main lobe is changed by 90° in the azimuth plane.

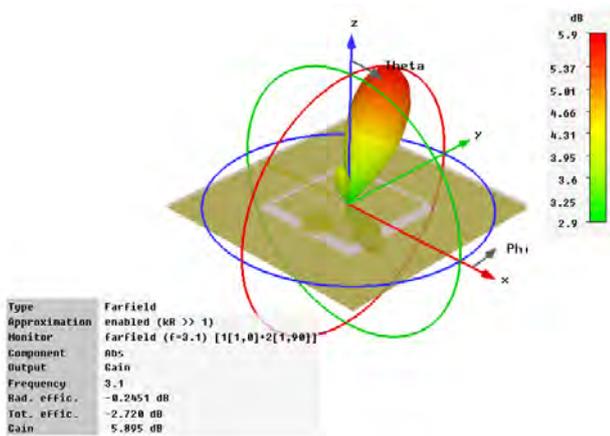


Fig. 3: Radiation pattern (3dB) for 90 degree phase shift.

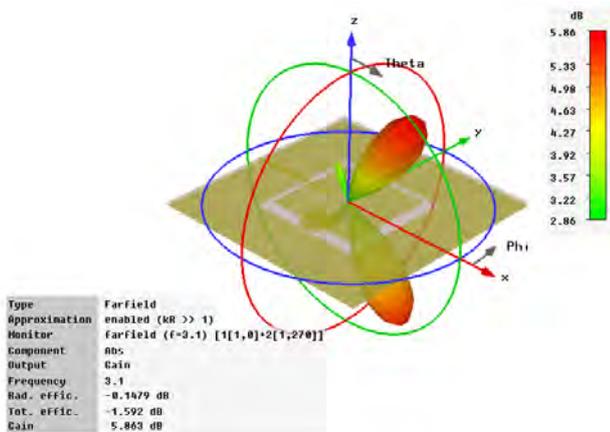


Fig. 4: Radiation pattern (3dB) for 270 degree phase shift.

A. Integration of power divider

The size of the antenna allows for a compact Wilkinson power divider [6] to be implemented on the same PCB. A circular topology was chosen for its compact size. The radius is 7 mm for a centre frequency of 3 GHz.

The power divider is placed on the top side of the antenna on the corner between the two feedlines. The CPW on the opposite side is excited through a via. The phase between the two elements is controlled by the length of the microstrip feedline. Two configurations are studied with feedline length corresponding to 90° and 270° phase shift (at the operating frequency of 3.1 GHz) in the patch feed. The antenna with integrated power divider is shown in Figure 5.

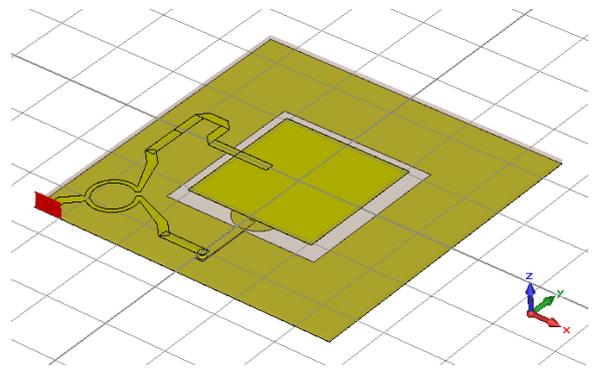


Fig. 5: Antenna with integrated power divider.

The antenna with the Wilkinson power divider shows a good match at 3.1 GHz for the two configurations. Figure 6 shows the return loss for a short and long configuration of the microstrip feed line corresponding to 90° and 270° phase shift at 3.1 GHz respectively.

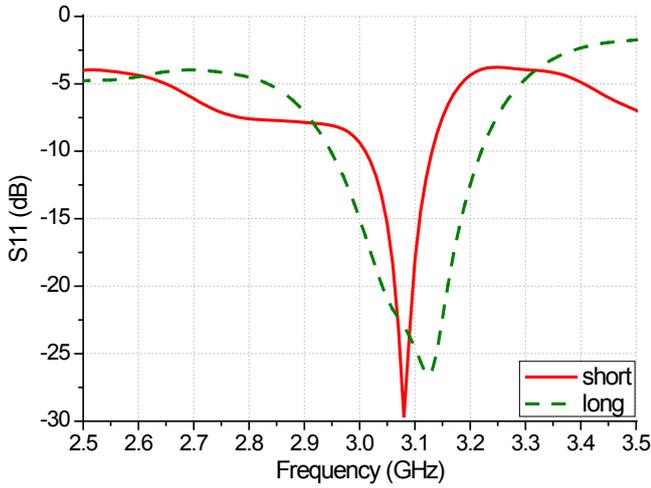


Fig. 6: Simulated return loss of the antenna with integrated power divider for different lengths of the microstrip feedline corresponding to 90° and 270° phase shift.

B. Reconfigurability

The ability to change the length of the feedline is implemented using PIN diodes [7] and two segments of distinct lengths of microstrip line. By switching the polarity of the bias of the diodes, the RF current path can be changed from the short to the long microstrip line.

To achieve the desired switching behaviour, two diodes are implemented in each current path. The diodes are oriented and wired to be switched to forward bias in the selected path and reverse bias in the other path. The bias voltage is ± 1.2 V across each diode in the forward and reverse bias states.

The antenna with integrated PIN diodes is shown in Figure 7. The DC bias cables are wired through holes in the groundplane.

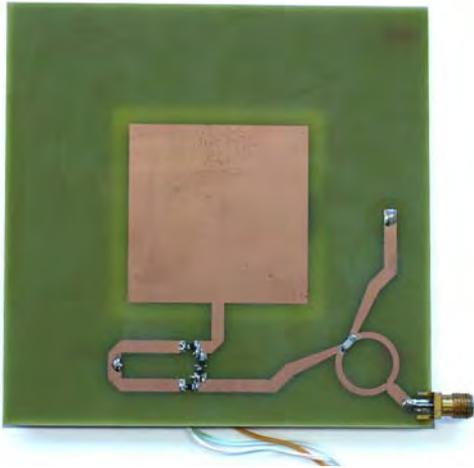


Fig. 7: Photograph of the antenna with integrated power divider and PIN diodes for switching the current path.

C. Prototypes

In addition to the fully integrated prototype with four diodes, a pair of antennas was fabricated using distinct lengths of microstrip feedline to the monopole antenna. This pair was used for reference measurements without the effect of diodes in the RF path.

III. RESULTS

The return loss of the antennas with integrated power divider was measured for the two prototypes with short and long current path in the microstrip feed. The return loss of both antennas is shown in Figure 8. The return loss at 3.1 GHz is better than -15 dB for both paths.

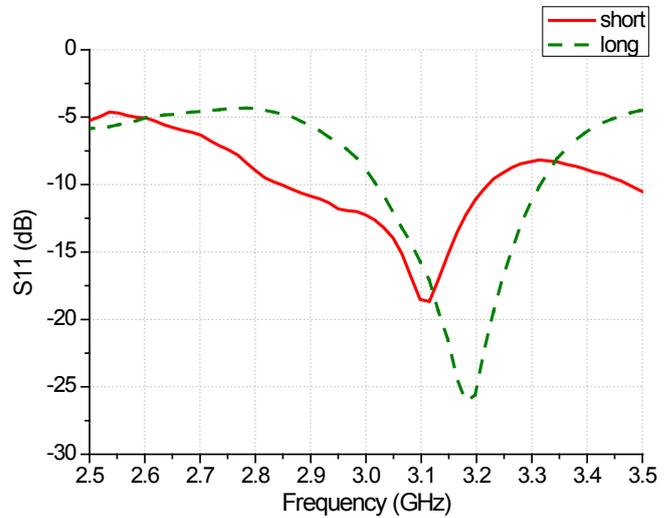


Fig. 8: Measured return loss of the antenna with integrated power divider for different lengths of the microstrip feedline corresponding to 90° and 270° phase shift.

The radiation patterns were measured in a farfield anechoic chamber for both phase shift configurations in both planes above the antenna. Figure 9 shows the pattern of the x - z ($\phi=0^\circ$) and Figure 10 of the y - z ($\phi=90^\circ$) planes.

It can be seen that the main beam for the short current path is in the x - z plane. When the antenna is switched to the long path, the lobe is reduced in the x - z plane and increased in the y - z plane. This demonstrates the switching of the pattern of the antenna. The main beam can be switched by 90° between the two elevation planes while it is $\theta=45^\circ$ above the horizon in both states.

The measured gain in the $\phi=0^\circ$ plane at $\theta=45^\circ$ is 1.1 dBi with the short microstrip line and drops to -13 dBi when switched to the long line. In the $\phi=90^\circ$ plane the measured

gain is 0.8dBi with the long line and -7dBi when switched to the short line. The dominant polarization is E_θ in both planes. The low gain values are attributed to insertion losses in the power splitter and feed arrangement.

antenna. However this would increase the complexity of the wiring and switching considerably.

IV. CONCLUSIONS

Our studies have shown the feasibility of this pattern reconfigurable antenna. In this paper a pattern reconfigurable antenna with the ability to change the direction of the main lobe of the radiation pattern between the two elevation planes was presented. Good pattern switching behaviour was confirmed in prototype measurement using discrete lengths of feedline. The reconfigurability was implemented using PIN diodes to change the length of the feedline to one of the driven elements electronically. The diodes introduce further losses and thus a drop in gain.

ACKNOWLEDGMENT

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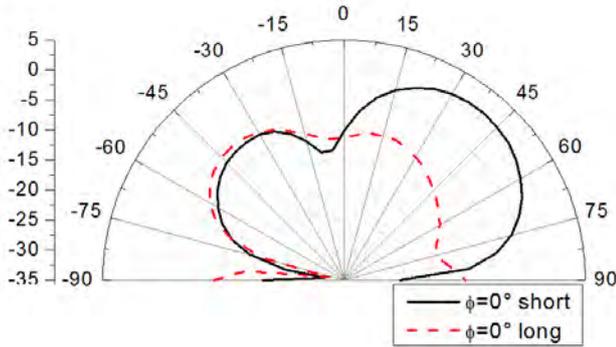


Fig. 9: Measured radiation pattern of the antenna in the $\phi=0^\circ$ plane for the short and long current paths.

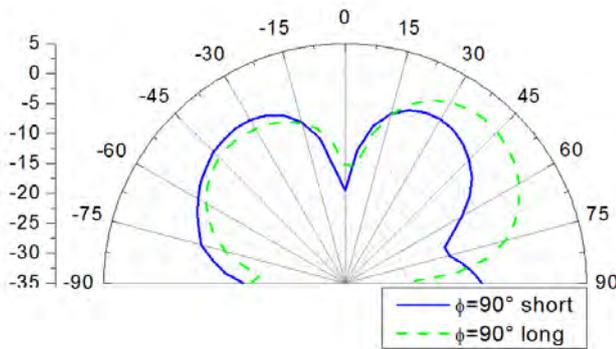


Fig. 10: Measured radiation pattern of the antenna in the $\phi=90^\circ$ plane for the short and long current paths.

The measurements of the integrated prototype show further losses introduced by the diodes in the current path. The gain is about 5dB lower in each switching state. We attribute this to the low reverse bias used in this prototype. An increase to -30 V of reverse bias might improve the performance of the