A Configurable Dual-H Type Planar Slot Antenna Applicable for Communication Well

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***Abstract*—A communication well is a well digged underground for data communication with base station using a specific antenna. To use communication wells, there is a need to design the specific antenna working at 836 MHz and 881 MHz frequency with each bandwidth of 50 MHz. The antenna should be embedded on the side of the well so that it does not take much room and the antenna should have a certain radiation direction. To meet requirements, a configurable dual-H type planar slot antenna with adjustable antenna directivity has been designed, fabricated and measured as part of out work. In this paper we studied the influence of edge structure on the antenna directivity and find out that antenna's radiation directivity is adjustable. By carefully designing the edge structure, we obtained the desired radiation pattern. All antenna parameters are optimized. Our work shows that the return loss of proposed antenna is -19 dB at 836 MHz and -15 dB at 881 MHz. The bandwidth spans from 800 MHz to 1 GHz. The measured maximum gain at each frequency is around 3 dB at a fixed direction. The measured results show that the propoesed antenna is applicable for communication wells.**

***Index Terms*—communication well; planar slot antenna; adjustable antenna radiation patterns; antenna edge structure.**

I. INTRODUCTION

Antenna has been widely used in modern society. It plays an important role in wireless communication system. Antenna's working frequency varies from one to one so that it meets the requirements of different wireless system for communication. The proposed antenna in this paper is based on the engineering application for communication wells. Generally a communication well is a well digged underground for data communication with base station using a specific antenna. In order to use a communication well, there is a need to design the specific antenna working at 836 MHz and 881 MHz frequency with each bandwidth of 50 MHz. The antenna should be embedded on the side of the well and able to communicate with base station faraway. So the antenna radiation pattern should have a fixed direction. Fig. 1 shows the working environment of antenna briefly. By comprehensively considering the working environment and the size of the antenna, planar antenna [1] using slotted technique is most suitable for the case and the proposed antenna ultimately meet the need of practical application.

In recent years slotted technique is widely used in planar antenna design. These antennas can be called planar slot antennas [2], [3]. As is known that planar slot antenna has the advantages of planarization, small volume, light weight, low profile, easy manufacture, low cost and easy shaped with carrier. These advantages match well with the antenna that is to be applied in wells. So in the beginning planar slot antenna design is adopted. Reference [4] proposes a H shaped slot antenna, it has no other spurious band, but the bandwidth is relatively narrow. Reference [5] presents a H-shaped slot antenna fed by microstrip coupling in the ground plane, the antenna can operate at triple frequency while the bandwidth and gain is unsatisfactory. In Reference [6] by adopting U shaped slot in H shaped radiation patch, broadband operating is achieved. This paper adopts the double-layer dielectric substrate. On the radiation patch of antenna, two H-shaped slot are applied to extend the current path without increasing its physical size thus miniaturizing the size of the antenna. On the ground plane there is a rectangular slot which can greatly broaden the bandwidth at target frequency. At the same time connecting the ground plane on negative side and positive side of the antenna by loading shorting pin at the edge of antenna, the antenna radiation pattern comes to one main directon.

II. CONFIGURATION OF THE ANTENNA

The detailed configuration of the proposed antenna is shown in Fig. 2. Two H-shaped slot is adopted in radiation patch to reduce the antenna size as the slot can extend the current path in limited space. On the back side of antenna, a rectangular slot in ground plane can extend antenna operating bandwidth at target frequency. The substrate is FR4 with thickness of 3mm and relative dielectric constant of 4.4. In this design the origin of coordinates coincides with the center of the dielectric substrate, as shown in Fig. 2 (a), (b), (c), the dot in red symbolizes the origin point. For fabrication convenience all the shorting pins are chosen to have a diameter of 0.8 mm and the center-to-center spacing are 4mm for short distance and 7mm for longer distance. The shorting pins at the edge of antenna connect the ground on the back side of antenna and ground on the front side

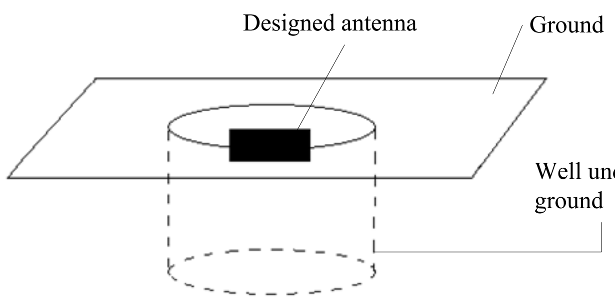


Fig. 1. The working environment of proposed antenna.

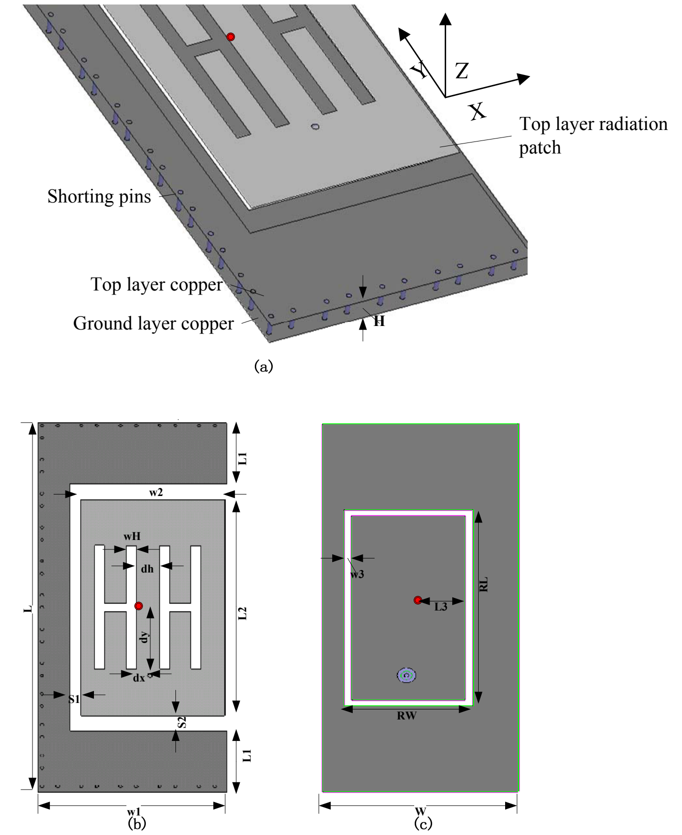


Fig. 2. Configurations of the proposed slot structures (a) overall 3D view of proposed antenna, (b) the front side of antenna with two H shaped slot, (c) the back side of antenna with rectangular slot.

TABLE I
OPTIMIZED PARAMETERS OF THE PROPOSED ANTENNA (UNIT: MILLIMETERS)

W	L	H	$w1$	$w2$	$w3$	$w4$	$L1$
50	120	3	47	37.5	6.5	2	20
$L2$	$L3$	S	RW	RL	dx	dy	dh
70	11.5	5	33	64	3.5	22	6

together. The proposed antenna is fed by coaxial probe and the feeding position has a great effect on the input impedence of the antenna. The optimized position is (-dx,dy) shown in Fig. 2. Extensive studies have been carried out in HFSS ver11 to optimize parameters to come up with the best values for the desired antenna. The optimized antenna parameters are shown in Table.

III. DESIGN SCHEME AND SIMULATION

In order to realize dual frequency operation, broaden bandwidth of antenna and make antenna radiation pattern adjustable, three techniques are used, namely dual H shaped slot on the radiation patch, rectangular slot in the ground plane and antenna edge structure. These techniques are discussed in the following.

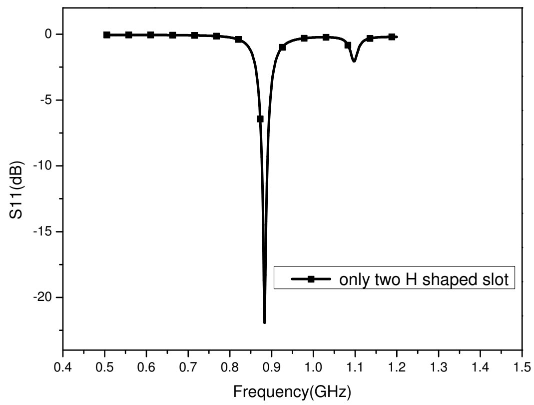


Fig. 3. Return loss where there are only dual H-Shaped slot in the radiation patch.

A. Dual H-shaped slot in the radiation patch

By adopting H slot in the radiation patch, the current path is extented without increasing its physical size and the resonant frequency decreases [7]. This helps to reduce the antenna size. In this paper dual H-shaped slot is applied in the radiation patch. Fig. 3 shows simulated S11 when there are only two H-shaped slot in the radiation patch. It can be seen that the resonant frequency is at 883 MHz with good resonant depth. However the bandwidth is narrow. The bandwidth at -10 dB is about 13 MHz. So it is necessary to improve the antenna structure.

B. Rectangular slot in ground plane

The antenna bandwidth can be broadened by slotting on the ground plane because the slot enables the current direction on the ground plane is in the opposite of that in radiation patch [8]. Based on this theory, a rectangular slot is applied in the ground plane. As the antenna structure changed, some antenna parameters have been optimized to get the result we want. Fig. 4 gives the comparison of S11 with and without rectangular slot in the ground plane. From the figure, it is noted that the bandwidth increases by a large margin.

C. Antenna edge structure

As is shown in Fig. 2, at the edge of antenna, shorting pins connect the ground plane on the back side and ground plane on the front side together. This edge structure enables the proposed antenna radiate energy concentrately at a certain direction. During our work, we find out that the antenna radiation pattern is adjustable by adjusting the size of antenna edge structure. The comparision about the effect of different antenna edge structure size on antenna radiation pattern is carried out in this paper. Fig. 5 and Fig. 6 shows the simulated radiation pattern of antenna1, 2, 3 in 836 MHz and 881 MHz in XOZ plane respectively. Antenna1, 2, 3 depicted in Fig. 5 and Fig. 6 represents three types of antenna. Antenna1 has no edge structure, the width of it is 0mm. Antenna2 has middle size edge structure, the width of it

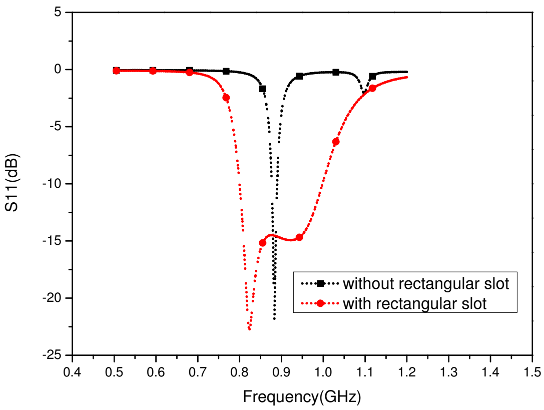


Fig. 4. Comparison of S11 with and without H shaped slot in the ground plane on the back side of antenna.

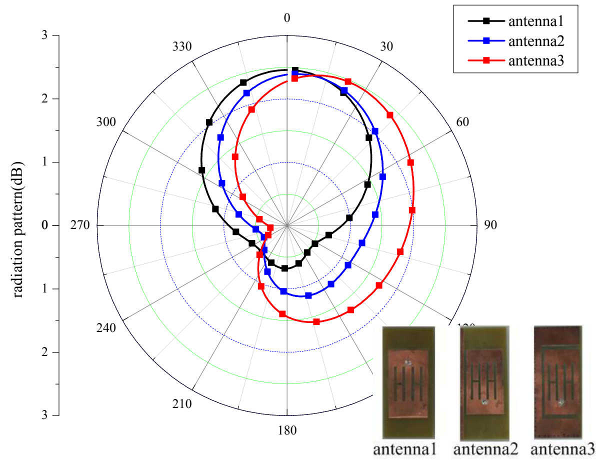


Fig. 6. Simulated radiation patterns of antenna1, 2, 3 at 881 MHz in XOZ plane.

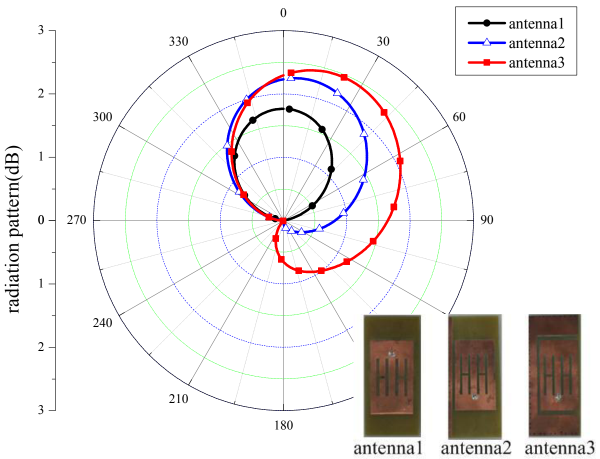


Fig. 5. Simulated radiation patterns of antenna1, 2, 3 at 836 MHz in XOZ plane.

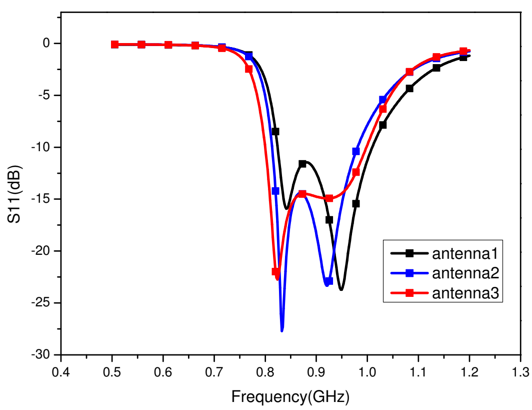


Fig. 7. Simulated S11 of antenna1, antenna2 and antenna3.

is 4mm. Antenna3 has the biggest size edge structure, the detail size is shown in Table I. From the figure it can be seen that antenna1's main radiation direction has no offset. Antenna2's main radiation direction is tilted about 15° with Z axis while antenna3's main radiation direction is tilted about 30° with Z axis, besides the max gain is bigger when the edge structure is larger. This illustrates that the antenna's directivity is adjustable. Fig. 7 gives the simulated S11 of antenna1, 2 and 3. The operating band of three antennas satisfy the requirement of communication well and as the size of edge structure increases, the whole band move to relatively lower frequency.

IV. Measured Results And Analysis

The proposed antenna with optimized structure is fabricated on FR4 substrate with r=4.4 and the thickness is H = 3 mm. The photo of the fabricated antenna is shown in Fig. 8.

The measured return loss is compared with simulation results in Fig. 9. Good agreement is achieved. The measured bandwidth is about 20% which is from 0.8 GHz to 1 GHz. Fig. 10 (a) and (b) shows the simulated and measured radiation patterns respectively in XOZ plane of the antenna at 836 MHz and 881 MHz. Obviously this antenna has an directional radiation pattern. The main beam in XOZ plane has been tilted by around 30 degrees due to the reflection of edge structure. The difference between simulated and measured radiation pattern both in 836MHz and 881MHz mainly due to the unwanted radiation by the feeding cable and the response of the anechoic chamber and the instability of the anechoic chamber also leads to a deviation. In general the edge structure has an impact on the radiation pattern, the bigger size of edge structure, the bigger angle tilted with the Z axis.

V. Conclusion

This paper presented a planar slot antenna with adjustable antenna directivity. The antenna is proposed to achieve good bandwidth and directivity by using slot technique and edge structure. The return loss of proposed antenna is -19 dB at

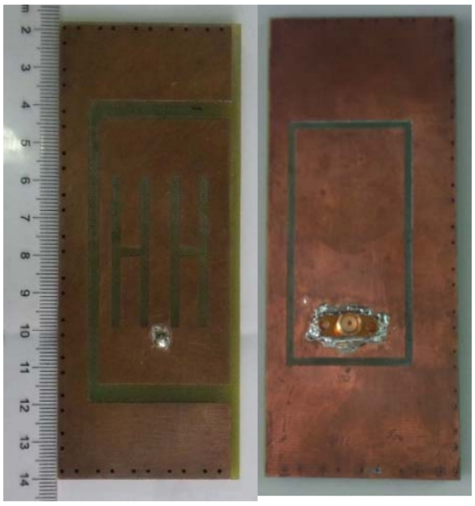


Fig. 8. Photo of the fabricated antenna.

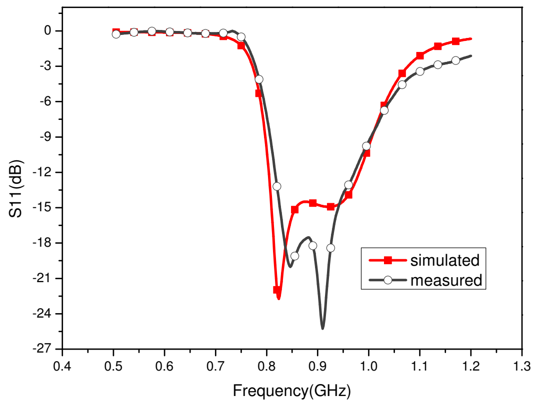
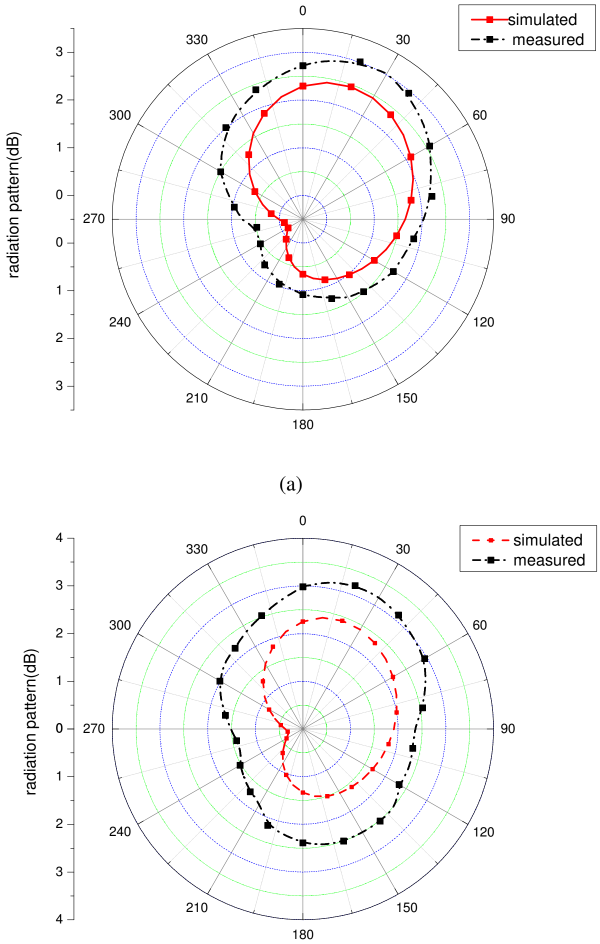


Fig. 9. Measured and simulated return loss of the proposed antenna.



(a)

(b)

Fig. 10. Measured and simulated radiation pattern in XOZ plane (a) 836MHz, (b) 881MHz.

836 MHz and -15 dB at 881 MHz. -10 dB bandwidth spans from 800 MHz to 1GHz. This work also focus on the impact of edge structure on the antenna radiation pattern. By comparing three types of antenna with different size of edge structure, our work shows that the directivity is proportion to the size of edge structure and by carefully designing the edge structure, we obtained the desired radiation pattern. The simulated maximum gain at each frequency is around 2.4 dB at the fixed direction and the measured gain of the proposed antenna is around 3 dB at each frequency. In general the proposed antenna provides directional radiation with reasonable gain and is applicable for communication wells.

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