A 35GHz Stacked Patch Antenna with Dual-Polarized Operations

Xue-Xia Yang, Guan-Nan Tan, and Ye-Qing Wang
School of Communications and Information Engineering
Shanghai University
Shanghai 200072, China

***Abstract*—A slot-coupled stacked patch antenna operating at 35GHz with dual-polarized operations is presented in this paper. To achieve wide bandwidth and high gain at 35GHz, four parasitic patches are located above the active element. The measured results show that the frequency bandwidth of S_{11} less than -10dB covers 30-40GHz and the isolation between two polarization ports is higher than 20dB at the center frequency of 35GHz. The peak gain at is 9dBi. Both theoretical and experimental results of reflection coefficient, isolation, and radiation patterns are presented and discussed.**

***Index Terms*— stacked patch antennas, dual-polarization, millimeter wave**

I. INTRODUCTION

Since 1960s, space solar power transmission (SPT) and microwave wireless power transmission (WPT) have become an interesting topic for an energy transmission [1]. It involves the conversion of DC power into microwave power at the transmitting end and forming the microwave power into electronically steerable microwave beams. The microwave energy is launched into space through a transmitting antenna. At the receiving end, the receiving antenna captures it back and the energy is then converted back into DC power [1, 2]. So, high gain receiving antenna is very important for the WPT system. Recently, microwave power transmission at millimeter wave is noticeable in biomedicine, fractionated reconfigurable satellites.

The microstrip antennas are popularly applied in communication and radar systems because of many good characteristics, such as low profile, ease to be integrated, and low cost [3]. By selecting the suitable dielectric constant and thickness of the substrate, microstrip antennas can be designed to operate on millimeter-wave [4-6]. In [4], a 2×2 microstrip patch antenna array operating at 60GHz is designed. However, the bandwidth is too narrow. In [5], a wideband 60GHz microstrip grid-array antenna is proposed based on the LTCC technology, which is relatively expensive now.

A microstrip antenna operates on resonant mode so its operation bandwidth is narrow. Some improvements have been suggested to expand the impedance bandwidth. In reference [7], a parasitic center patch is used to enhance the S11≤-10dB bandwidth of a printed wide-slot antenna to 80% (2.23-5.35GHz). In reference [8], a wide band dual-beam microstrip antenna is proposed by using the U-slot technique. The antenna operating frequency range is 5.18-5.8GHz with VSWR less than 2, which corresponds to 11.8% impedance bandwidth at 5.5GHz.

Usually, the WPT systems require communication function [9, 10]. In [9], a two-port with dual-polarization printed microstrip rectenna is presented. One port is used for power receiving at 5.78GHz, and the other is used for data communication at 6.1GHz. In [10], a triple-band antenna is suggested for biotelemetry with data telemetry (402MHz), wireless powering transmission (433MHz), and wake-up controller (2.45GHz).

In this paper, a 35GHz slot-coupled stacked antenna operating on two orthogonal linear polarization states is proposed. The simulation and measurement show that the antenna has a wide bandwidth, high gain and good isolation between two polarizations. This dual-polarized patch antenna can be used as the receiving antenna in a wireless microwave power transmission system with communication function.

II. DESCRIPTION OF ANTENNA

The geometry of the proposed antenna is shown in Figure 1. There are three dielectric substrate layers, which are labeled as layer a, b and c. The three substrate layers are all Rogers RT/duroid 5880 with the relative permittivity of 2.2 and the dielectric loss tangent $\tan\delta$ of 0.0009. Three layers have different thickness of h_a, h_b and h_c. The active patch is placed on the top of layer b. Four parasitic patches on the top of layer c are placed over the four corners of the active patch. The antenna has two feed ports of port 1 and port 2. The characteristic impedance of the two feed lines on the bottom of layer is 50 Ω. Two perpendicular slots on the ground plane are used to couple two orthogonal linear polarization waves. The bottoms of two feed lines are bended to realize impedance match.

Not only the bandwidth but also the gain of this patch antenna is improved by two methods. The first one is the stacked multi-layer patch structure. The second one is the four parasitic patches. The perpendicular coupling slots leading to a high isolation between two linear polarization ports and low cross-polarization.

The antenna performances is determined by many geometrical parameters, such as the sizes and position of two slots, the side lengths of the active and parasitic patches, and the distance between parasitic patches and feed lines.

This work was supported by the National Natural Science Foundation of China (No. 61271062), and STCSM (08DZ2231100).

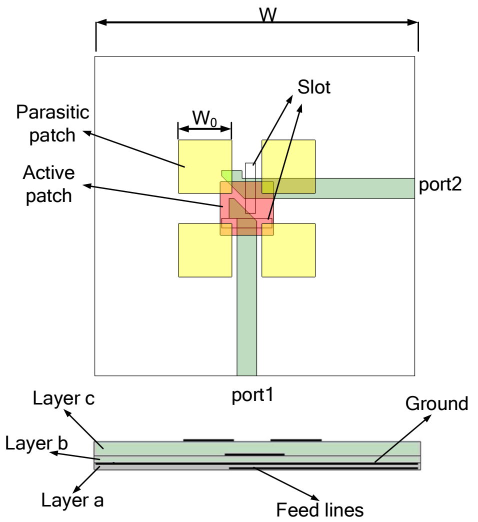


Figure 1 The structure of the proposed antenna

III. SIMULATION AND MEASUREMENT

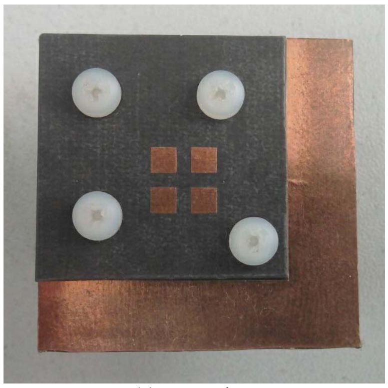
The optimized dimension of the antenna is shown in table 1. The slots dimensions are 0.4mm×2mm. The size of the parasitic patch is the same as the active patch. The width of the feed line is 0.8mm. The proposed antenna is optimized and simulated using the 3D-fullwave simulator of Ansoft HFSS 12.

Table 1 Dimension of the proposed antenna

w	w_0	h_a	h_b	h_c
26	2.1	0.254	0.254	0.508

The Fabricated antenna is presented in Fig. 2. The ground is larger than layer b to measure the antenna conveniently. The microstrip feed line of the antenna was connected to an end launch connector 149-02A-5 of Southwest Microwave. The reflection coefficient was measured by the vector network analyzer of Agilent PNA-N5227A.

The simulated and measured reflection coefficient S_{11} and S_{22} for two feed ports are shown in Fig. 3. The bandwidths of S_{11} and S_{22} less than -10dB cover from 30GHz to 40GHz, which is about 28%. Due to a slight asymmetry of the two feed lines and slots, S_{11} and S_{22} curves are not exactly the same. The simulated and measured isolation between two polarization ports are presented in Fig. 4. Due to limitation of test fixture, the measured S_{21} has many ripples. But the trend is relatively the same. At 35GHz, the isolation is about 22dB. Throughout the frequency range from 30GHz to 40GHz, the isolations are all higher than 20dB. The high isolation of this dual-polarized antenna is very useful for many practical applications.


(a) Front view

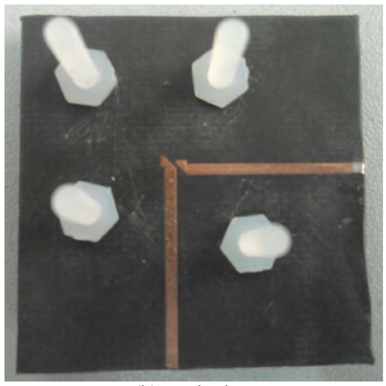
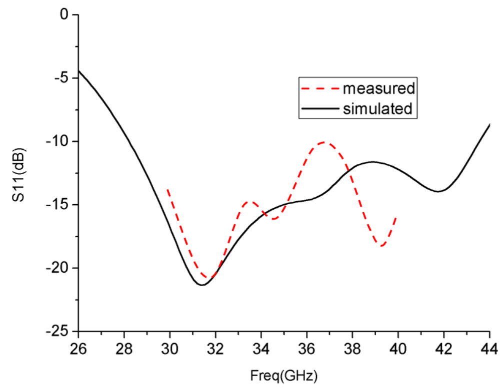
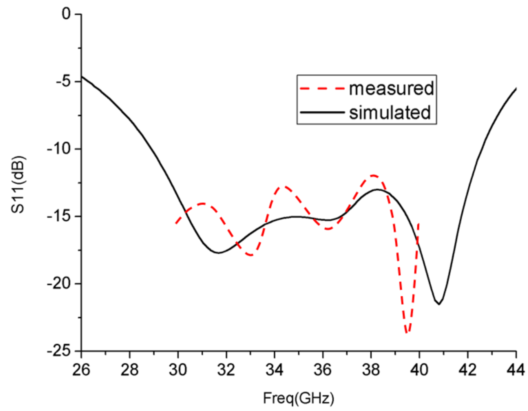

(b) Back view

Fig. 2 Fabricated antenna



(a) S11



(b) S22

Fig. 3 S_{11} and S_{22} vs. frequency

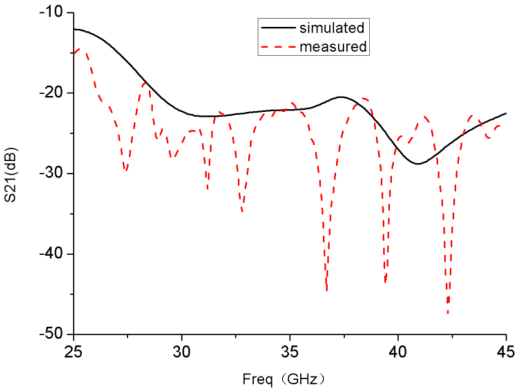
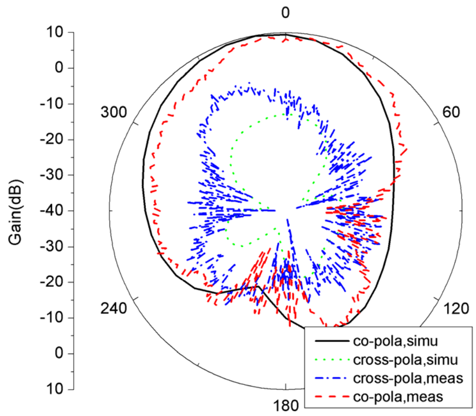
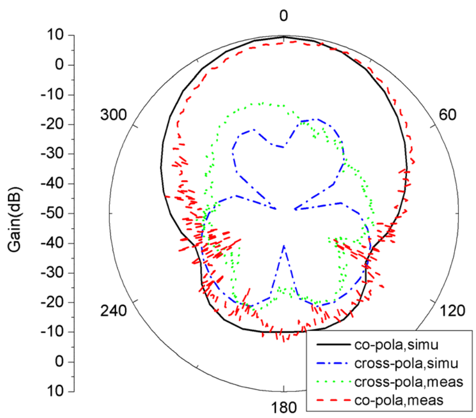


Fig. 4 Isolation between two ports

The radiation characteristics were measured in the anechoic chamber. The simulated and measured E plane and H plane radiation and cross-polarization patterns at the frequency of 35GHz of port1 and port2 are presented in Fig. 5, Fig. 6, respectively. It can be seen that the simulated results almost coincide with the measured ones . The cross-polarization levels are lower about -20dB than the main polarization. The simulated and measured antenna gain between 30GHz and 40GHz of port1 and port2 are shown in Fig. 7. The measured gains of the two ports are all about 9dBi at 35GHz.

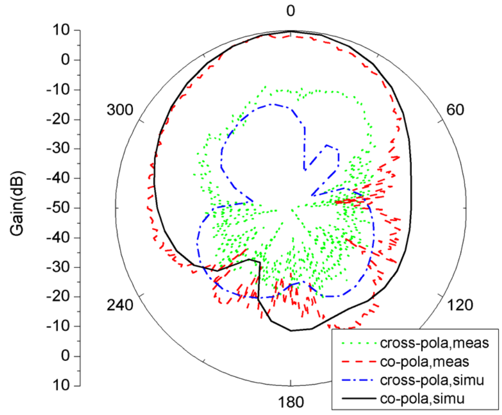


(a) Pattern of E plane

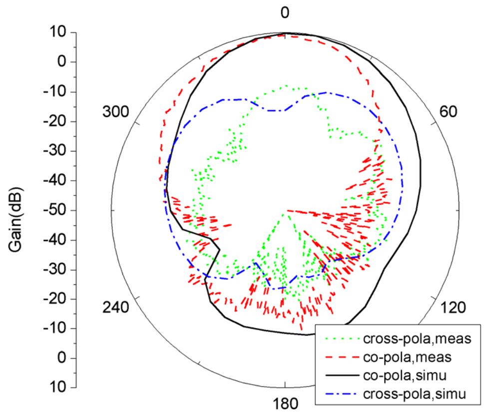


(b) Pattern of H plane

Fig. 5 Antenna pattern of port1 at 35GHz

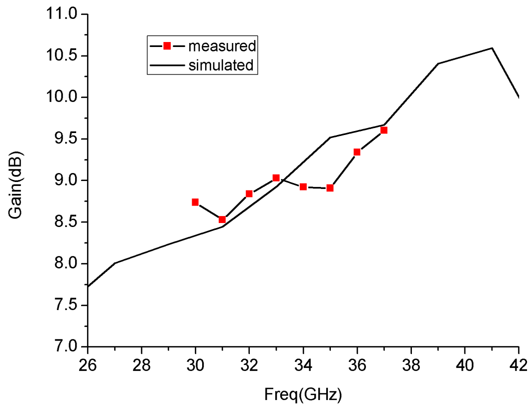


(a) Pattern of E plane

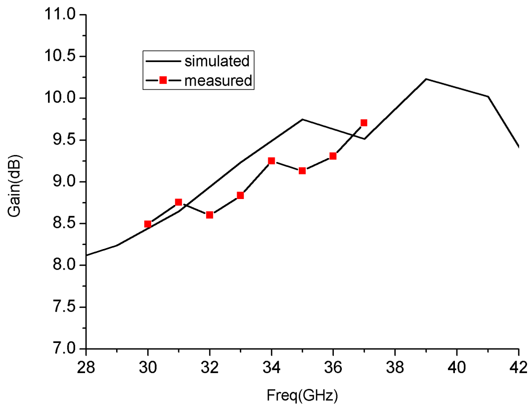


(b) Pattern of H plane

Fig. 6 radiation patterns of port2 at 35GHz



(a) Port 1



(b) Port 2

Fig. 7 Measured and simulated gains vs. frequency

IV. CONCLUSIONS

This paper proposed a 35GHz slot-coupled stacked patch antenna operating on dual orthogonal linear polarization states for wireless microwave power transmission. One linear polarized wave excited by port 1 is used to receiving microwave power, while another one activated by port 2 could be used to communicate. This antenna has good performances of wide-bandwidth, high isolation, low cross-polarization level and high gain. The measured reflection coefficient exhibits an impedance bandwidth over 30~40GHz and the isolation between two polarization ports is better than 20dB over the bandwidth. The cross-polarization levels in both E and H planes are lower than -22dB. This dual-polarization antenna is easy to be expanded to a large-scale array.

REFERENCES

[1] B. Strassner and K. Chang, "Microwave Power Transmission: Historical Milestones and System Components," Proceedings of the IEEE, vol. 101, no. 6, pp. 1379-1396, 2013.

[2] R. M. Dickinson, "Power in the sky: Requirements for microwave wireless power beamers for powering high-altitude platforms," Microwave Magazine, IEEE, vol. 14, no. 2, pp. 36-47, 2013.

[3] Kin-Lu Wong, Compact and broadband microstrip antennas, New York, John Wiley & Sons Inc., 2002.

[4] B. Biglarbegian, M. Fakharzadeh, D. Busuioc, M. R. Nezhad-Ahmadi, and S. Safavi-Naeini, "Optimized Microstrip Antenna Arrays for Emerging Millimeter-Wave Wireless Applications," IEEE Transactions on Antennas and Propagation, vol. 59, no. 5, pp. 1742-1747, 2011.

[5] S. Zhang and Y. P. Zhang, "Analysis and synthesis of millimeter-wave microstrip grid-array antennas," IEEE Antennas and Propagation Magazine, vol. 53, no. 6, pp. 42-55, 2011.

[6] A. Bondarik, J. Dong-Suk, K. Joung-Myoun, and H. Y. Je, "60 GHz system-on-package antenna array with parasitic microstrip antenna single element," Asia-Pacific Microwave Conference 2008, APMC 2008, pp. 1-4, Dec. 2008.

[7] Y. Sung, "Bandwidth Enhancement of a Microstrip Line-Fed Printed Wide-Slot Antenna With a Parasitic Center Patch," IEEE Transactions on Antennas and Propagation, vol. 60, no. 4, pp. 1712-1716, 2012.

[8] A. Khidre, L. Kai-Fong, A. Z. Elsherbeni, and Y. Fan, "Wide Band Dual-Beam U-Slot Microstrip Antenna," IEEE Transactions on Antennas and Propagation, vol. 61, no. 3, pp. 1415-1418, 2013.

[9] Xue-Xia Yang, Chao Jiang, Atef Z. Elsherbeni, Fan Yang, and Ye-Qing Wang, "A Novel Compact Printed Rectenna for Data Communication Systems", IEEE Transactions on Antennas and Propagation, Vol. 61, no. 5, pp. 2532-2539, 2013.

[10] H. Fu-Jhuan, L. Chien-Ming, C. Chia-Lin, C. Liang-Kai, Y. Tzong-Chee, and L. Ching-Hsing, "Rectenna Application of Miniaturized Implantable Antenna Design for Triple-Band Biotelemetry Communication," IEEE Transactions on Antennas and Propagation, vol. 59, no. 7, pp. 2646-2653, 2011.