A Stacked Broadband Circularly Polarized Microstrip Antenna
Boya Zhang and Zhengjun Li

ABSTRACT
This article presents the design of an innovative stacked structure of a wideband circularly polarized microstrip antenna. The circular patch design with L-probes feed technology and four reverse-phase feeding technology broadens the antenna impedance bandwidth and circularly polarized bandwidth. Two antennas are stacked longitudinally, both upper and lower layers of antennas are fed by probes. The impedance bandwidth is effectively doubled, and it can continue to stack and further expand the bandwidth. The direction of the maximum radiation of the whole working band is the same and points to the reflector antenna, which makes it possible to maximize the utilization of radiation energy and is more suitable for feeding antennas. The simulation results show that the antenna possesses an impedance bandwidth of 81.4% (VSWR<2), the axial ratio is not greater than 2.8dB, and the peak gain of the antenna is 10dBi.

Key words: Patch Antenna; Broadband; Circular Polarization

1. INTRODUCTION
A wideband circularly polarized feed irradiator is needed in space-borne system, to achieve the acquisition of ground target wave signals and source localization for specific coverage on the ground. For the demand of satellite communication, the following requirements should be provided by feeding antennas: In order to meet the requirements of circular polarization, the operating bandwidth should be 0.2GHz-0.5GHz; high gain characteristics to ensure that the reflector antenna can capture enough energy; The radiation pattern varies symmetrically with frequency and has a stable beam width; low profile, small volume, light weight, easy to install. Therefore, a stacked broadband circularly polarized antenna is designed based on the above research background.

Generally speaking, the thickness of microstrip patch antenna is very small compared with the wavelength, so it has the characteristics of low plane. And it is easy to match the shells of various electronic systems such as aircraft, satellites, etc. It is easy to meet the design requirements of circular polarization, multi-polarization and multi-band, and has the characteristics of small size, light weight and low cost, so it is very easy to be used in large-scale production. However, its narrow band characteristics restrict the wide application of microstrip antennas.

Therefore, broadband and circular polarization are the difficulties of this design. Commonly used methods to expand the impedance bandwidth of microstrip antennas can be summarized as follows: (1) Reduce the Q value of the equivalent circuit, such as increasing the thickness of substrate, decreasing the εr and increasing . (2) Improving the feeding method, such as feed through electromagnetic coupling, load capacitance.

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element, add impedance matching network and so on. (3) Modify the equivalent circuit as multi tuning loop, such as add parasitic patch (double or coplanar configuration), load U shape, E shaped slot, etc[1]. According to the literature[2]-[9], the performance of microstrip antennas with different feeding modes and structures is compared. The multi-layer patch can increase the bandwidth to nearly 70% by coupling feeding, but there is still a certain distance from the 86% of the design requirements, the complexity of impedance matching will be increased by adding the new coupled patch. Therefore, the single antenna structure is difficult to meet the design requirements.

A new type of stacked microstrip antenna is presented in this paper. two antennas are stacked longitudinally, both upper and lower layers of antennas are fed by probes, the feed probes of the upper antenna is drawn from the coaxial cable passing through the center of the lower antenna. Reduce mutual coupling between antennas, so that two antennas can work independently in their frequency bands to achieve broadband circular polarization, when the two frequency bands are near and connected, the working bandwidth can be widened.

2. STRUCTURE AND DESIGN OF AN ANTENNA

The geometric structure of the stacked microstrip antenna is shown in Figure 1. The antenna is composed of two layers of circular patch microstrip antennas, from bottom to top are, respectively, antenna 1 and antenna 2. The antenna 1 has a working center frequency of 0.25GHz, a coverage frequency of 0.2G-0.3GHz, and the antenna 2 with a working center frequency of 0.4GHz and a coverage frequency of 0.3G-0.5GHz. Because the antenna 1 has lower working frequency and larger patch size, it is placed at the bottom of the stacked antenna. the four feed probes of the upper antenna 2 is fed by the coaxial cable connected with feeding network passing through the center of the lower antenna. Reduce mutual coupling between antennas, so that two antennas can work independently in their frequency bands to achieve broadband circular polarization, when the two frequency bands are near and connected, the working bandwidth can be widened. This is the innovation of this study.

Each layer of antenna consists of a circular patch, an air layer and four L-probes. The introduction of a thick air layer contributes to the widening of the working bandwidth of the antenna, and for microstrip antennas with thick dielectric layers, longer feed probes introduce large inductances. The horizontal metal piece on top of the L-probe is combined with the radiating patch to create a capacitance. Changing the size of the metal piece and the distance between the metal piece and the patch produces enough capacitance to compensate for the probe inductance and thereby increase the bandwidth. In order to ensure the circular polarization bandwidth of the antenna, a four-point inverting feed technique is employed. The four feed ports have the same amplitude and phase in the order of 0°, 90°, 180° and 270°, which ensures that the phase difference between the two relative probes is 180°. The advantage is
that not only can the cross polarization caused by the mutual coupling between them can be offset, the circular polarization axial ratio is greatly widened, and the symmetry of the pattern is improved compared with the conventional design.

The dimensions for the lower layer antenna 1 are as follows. The circular patch with radius of $R_1=293\text{mm}(0.244\lambda_1)$ and the height $H_1=70\text{mm} (0.058\lambda_1)$. The patch is excited by four L-probes arrayed by 90° phase difference at the bottom of patch, $d_1=623\text{mm} (0.51\lambda_1)$, each probe with radius $r_1=4.85\text{mm} (0.004\lambda_1)$, height $h_1=48.5\text{mm}(0.04\lambda_1)$, length $L_1=233\text{mm} (0.194\lambda_1)$. The ground of the antenna is round, and the radius $R_{g1}=819\text{mm}(0.68\lambda_1)$, thickness $t_1=5\text{mm}(0.0042\lambda_1)$, the substrate inside has relative permittivity $\varepsilon_r=2.65$. A feed network printed on the other side of the substrate is used to feed the L probe through a small round hole on the ground. $\lambda_1$ is the free space wavelength at 0.25GHz. The dimensions for the upper layer antenna are $R_2=196\text{mm}(0.261\lambda_2)$, $H_2=49\text{mm} (0.065\lambda_2)$, $d_2=405\text{mm} (0.54\lambda_2)$, $r_2=3.15\text{mm} (0.004\lambda_2)$, $h_2=36\text{mm} (0.05\lambda_2)$, $L_2=137\text{mm} (0.183\lambda_2)$. $\lambda_2$ is the free space wavelength at 0.4GHz.

3. DESIGN OF FEEDING NETWORK

The feeding network of the proposed antenna is shown in Fig. 2. It is made up of three Wilkinson power dividers. It can provide two outputs with equal amplitude and 180° phase difference. The phase change can provide four L-shaped probes with wide frequency and equal input power with phase are 0°, 90°, 180° and 270°. The phase difference of the port is within 2 degrees. Each power divider is connected to a 1000-chip resistor for good isolation between the network output ports. The dimensions for the two networks are $a_1=12.46\text{mm}$, $b_1=214.83\text{mm}$, $c_1=13.66\text{mm}$, $d_1=7.69\text{mm}$, $e_1=65.66\text{mm}$, $f_1=10\text{mm}$; $a_2=7.79\text{mm}$, $b_2=134.17\text{mm}$, $c_2=13.66\text{mm}$, $d_2=7.69\text{mm}$, $e_2=41.01\text{mm}$, $f_2=6\text{mm}$.

![Figure 1. The basic structure of antenna.](image)
4. ANALYSIS OF SIMULATION RESULTS

In the designed structure, microstrip antenna 2 is placed at the top, which has an impact on microstrip antenna 1. So, first of all, through HFSS simulation to compare the performance parameters of microstrip antenna 1 with or without microstrip antenna 2. When there is no microstrip antenna 2, the HFSS simulation results of microstrip antenna 1 are shown in the figure. Figure 3 shows the standing wave ratio with frequency change, and the impedance bandwidth (SWR ≤ 2) is 42.2% (202MHz to 310MHz). In figure 4, it can be observed that the axial ratio of the entire working frequency band is less than 1.5dB, the circular polarization performance is very good, and the maximum gain reaches.

When microstrip antenna 2 exists, adjust the distance between the two antennas, the HFSS simulation results of microstrip antenna 1 in the overall structure are shown in the figure. Figure 5 shows that the impedance bandwidth (SWR ≤ 2) is 44.1% (198MHz to 310MHz). Figure 6 shows that the axial ratio of the entire working frequency band is less than 0.9db and the maximum gain reaches 10dBi. It can be seen from the simulation results that the existence of microstrip antenna 2 makes the bandwidth higher, the axial ratio less and the gain of microstrip antenna 1 lower. Therefore, the innovative stacked structure in this paper does not affect the independent work of the two antennas, which proves the feasibility of the structure. Next, the radiation characteristics of antenna 2 in the overall structure are observed. The radiation characteristics of antenna 1 and antenna 2 above jointly constitute the radiation characteristics of laminated antenna.

The HFSS simulation results of microstrip antenna 2 in the overall structure are shown in the figure. Figure 7 shows the standing wave ratio with frequency change, and the impedance bandwidth (SWR ≤ 2) is 43.2% (303MHz to 470MHz). In figure 8, it can be observed that the axial ratio of the entire working frequency band is less than 2.8dB, and the circular polarization performance is very good. The maximum gain is 9.68dBi. Figure 9 shows the radiation directions of multiple frequencies, including 0.2GHz, 0.3GHz, 0.4GHz and 0.47GHz. At the high and low frequency points and the center frequency points of the passband, the main polarization radiation direction diagram of the antenna is consistent and has good symmetry. In summary, the working
band of antenna 1 and antenna 2 is connected to each other. Therefore, the bandwidth of the whole laminated antenna reaches , and the radiation performance is good. It meets the design requirements and realizes wide band circular polarization.

Figure 3. The standing wave ratio of antenna 1.

Figure 4. The axial ratio of antenna 1.

Figure 5. The standing wave ratio of antenna 1 in the whole structure.
Figure 6. The axial ratio of antenna 1 in the whole structure.

Figure 7. The standing wave ratio of antenna 2 in the whole structure.

Figure 8. The axial ratio of antenna 2 in the whole structure.
5. CONCLUSION

This paper introduces the design and simulation of a innovative stacked structure of a broadband circularly polarized microstrip patch antenna. The circular patch design with L-probes feed technology and four reverse-phase feeding technology broadens the antenna impedance bandwidth and circularly polarized bandwidth. Two antennas are stacked longitudinally, both upper and lower layers of antennas are fed by probes. The impedance bandwidth is effectively doubled, and the structure is simple. It can continue to stack and further expand the bandwidth. As a feed, Because of its longitudinal laminated structure, the maximum radiation direction of the whole working band is the same and points to the reflector antenna, makes it possible to maximize the utilization of radiation energy and is more suitable for feeding antennas. The HFSS simulation results reveal that this antenna can achieve a bandwidth of 81.4% (VSWR<2), an axial ratio less than 2.8dB, and a peak gain of 10dBi. This antenna should find application in Satellite communications communication systems.

REFERENCES