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Wideband Dual-linear Polarized Stacked Patch Antenna with Asymmery Feeding

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Abstract

The narrow working bandwidth of microstrip antennas limits their applications in in radar and communication systems. Staked patch antenna based on aperture coupling and asymmetry feeding technique was proposed in this paper. A cross-shape aperture imbedded in the ground plane with asymmetry feeding structure provided a relative wideband electromagnetic coupling and allowed a high isolation between two orthogonal ports.The asymmetry feeding structure was composed of two microtrip lines locating above and under the ground plane. U-shape microtrip line adjusted microstrip feeding line characteristic impendence with antenna input impendence in a broad band. Experimental results indicated that an impendence bandwidth of 35.3%, better than 4.5dBi antenna gain; better than 30dB isolation and good cross-polarization were available. Measured results proved that stacked patches using asymmetry feeding structure through aperture coupling to expand working frequency and realize dual-linear polarization was effective.

Key Words: *Wideband Antenna, Dual-Linear Polarization, Stacked Patch Antenna, Aperture Coupling, asymmetry feeding*

1. Introduction

Patch antennas, especially microstrip line fed patch antennas, are widely used from military to commercial communication systems [1] due to their light weight, small size, easy integration and relative low cost. In addition, patch antennas can be easily integrated with a feeding network so as to form a large antenna array [2]. Dual-polarized patch antennas are desirable for dual-polarized applications because of their constant radiation patterns and stable phase center.

In order to excite the patch antenna orthogonally, two off-set slots or crossing slot are cut in ground plane which are excited by microstrip line underneath [3]-[5]. Each slot excites the radiating and parasitic patches in one linear polarization. In [4] two offset apertures with H-shape in the corner of ground plane are adopted to couple the electromagnetic fields to the radiating patch. An impedance bandwidth of 24.4% and high isolation between two ports is realized. Although the antennas have achieved satisfied isolation between ports, the bandwidth of the antenna remains to be expanded. In [5] dual-layered feeding technique is proposed in dual-polarized antenna design. Wide impedance bandwidth is achieved by using different substrate with variable dielectric constant. Multilayer air increase antenna profile and design complexity.

How to realize dual-linear polarization in patch antenna without complicated feeding network.and expand their relatively narrow bandwidth are still concerned Researchers have proposed many ways to overcome this drawback of patch antenna. Such as in [6] [7] L-probe technique is introduced to expand the operation frequency bandwidth of patch antenna. In [6] L-probe and aperture are utilized to feed the patch orthogonally to obtain circular polarization. The antenna shows a good return loss bandwidth and 3-dB axial ratio bandwidth. However, an L-probe suspended between the feed line and patch is not convenient for circuit integration. Also, stacked patches technique has been used to extend bandwidth [8]-[10]. In [10] a dual-polarization stacked patch antenna with low return losses, high isolation and 25% impedance bandwidth is excited by a pair of crossing slots in the ground plane. Each slot is fed by a couple of symmetrical microstrip lines on the same layer. An air bridge is employed to avoid the

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microstrip line intersection. However the air bridge increases the fabricating complexity and deteriorates the isolation between ports if a wide band of frequency was demanded.

In this paper, Cross-shape aperture in ground plane is available for electromagnetic coupling to stacked patches. Microstrip line located at different substrate layer is used to feed the cross-shape apertures. Microstrip transmission line underneath the ground plane is to excite stacked patches in one linear polarization and the U-shape transmission line abave the ground plane is to feed the antenna in the other polarization. Unlike symmetrical microstrip lines in [10] [11] which is more rigid in antenna design, asymmetrical feeding way in this paper also provides high port isolation and high polarized purity. Stacked patches together with aperture coupling technique, allow a wide impedance bandwidth. According to the requirement, the antenna is designed and optimized by Ansoft HFSS. Then a prototype has been realized and its measurements have been carried out which show good performance within wide impedance bandwidth. The main innovation here is proposed an asymmetrical feeding concerpt that dual polarized antenna feeding structure has not to be limited to exactly symmetrical way. Asymmetrical feeding structure also can realized broad bandwidth, high isolation, good radiation pattern and low cross-polarization in dual-linear polarized stacked patch antenna.The proposed antenna can be used in dual linearly polarized planar array as electromagnetic vector cell [12].

2. Research Method

Shown in Figure 1, this stacked patch antenna (SPA) is composed of two square copper patches (parasitic patch and radiating patch). Parasitic patch is etched on back of dielectric substrate which shields the patch underneath. Patches on dielectric substrate with higher dielectric constant have narrower bandwidth than substrate with lower dielectric constant [10]. But Low dielectric constant goes against the principle of miniaturization antenna size. Trade off of dielectric constant is necessary. Figure 2 shows the top view of feeding network and stacked patches. Dual polarization requires symmetrical radiation element for both ports, so square patches are adopted. As in Figure 3 Rogers 5880 (dielectric constant ε_1 2.2 and h_1 height 0.78mm) and Rogers R03003 (dielectric constant ε_3 3.0 and height h_3 1.5mm) are used for parasitic patch substrate and radiating patch substrate respectively. The air layer between two substrates is beneficial to widen the working bandwidth. Thick air layer is favorable to expand working bandwidth and should be optimized so as not to increase antenna profile. Figure 4 shows the aperture architecture in ground plane. Two microstrip lines locating at different layer share a common ground plane. These two microstrip lines are orthogonal to provide dual-linear polarization. This feeding way allows a high isolation between two orthogonal ports [5] and avoids the air bridge when feeding networks are in same layer. The height of two Rogers 5880 substrates ($h_4 = h_5$ 0.508mm) for two microstrip feeding line is same in order to obtain same mutual coupling between feeding network and aperture.

As shown in Figure 4, the symmetrical cross-shape aperture has a narrow center to control ports isolation and a wider tail to match with the microstrip feeding line. Stair case of cross-slot is the result of optimization that keeps a low return losses and high port isolation. Coupling between microstrip line and slot is decided by the width of slot center [9]. Electromagnetic field is directly coupled to the slot which is orthogonal to the microstrip line. Cross-shape slot in groud plane is self-intersected at center where the electromagnetic field is strongest. As shown in Figure 3, if microstrip line 1 employs same shape as microstrip line 2, isolation between two ports will decrease. U-shaped microstrip line 1 excites the aperture slight away from slot center while coupling from Microstrip line 2 is exactly in the slot center. So strongest electrc fields coupled from microstrip line 1 and Microstrip line 2 will be slightly apart from each other in the slot. Thus the decreased isolation caused by intersection in cross-shape slot will be improved. Microstrip line 1 located above the ground plane can couple directly to the patches. Thanks to electrically thick substrate (1.5mm), direct coupling from microstrip line 1 and patches is minimal. Coupling from two orthogonal slots remains approximately the same even different kinds of microstrip feeding line are employed to excite the cross-shape aperture.

Impendence transformation is necessary in both microstrip feeding lines because microstrip line with 50Ω characteristic impendence have to be used to connect with SMA conntector. While at the end of microstrip feeding lines, this characteristic impendence should match up to the slot characteristic impendence in ground plane. As shown in Figure 2, microstirp line 1 has a T-junction to transform a single microstrip line to a couple of microstrip lines. At the end of microstrip line 1 a tunable sub with an open circuit is used to compensate the inductance found in the working frequency band. Cross-slot in the ground plane is used not only for coupling electromagnetic wave to the patches but also for the antenna input impendence matching. According to optimization results from Ansoft HFSS, specific SPA with feeding networks parameters and cross-shape aperture parameters are shown in Table 1 and Table 2 respectively.

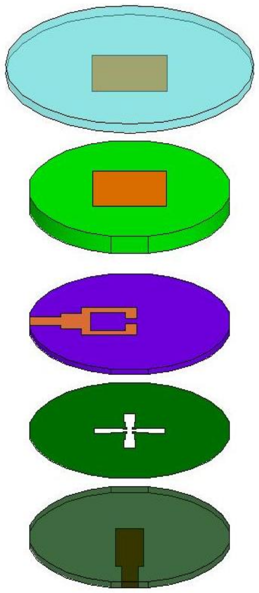

Figure 1. Geometry of dual-linear polarized antenna

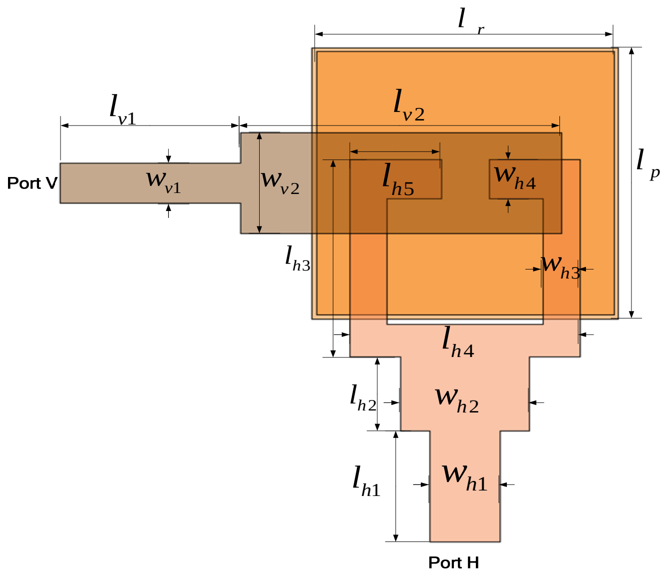

Figure 2. Top view of SPA without coupling aperture on ground plane

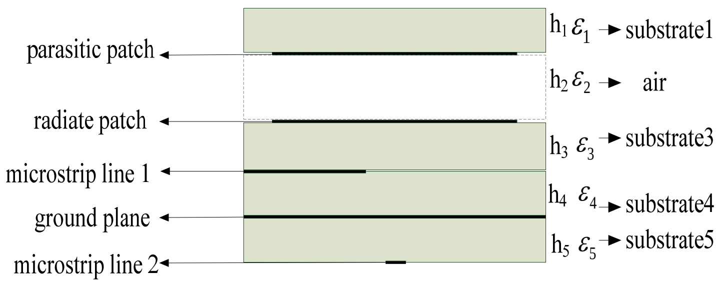

Figure 3. Cross-sectional view of SPA

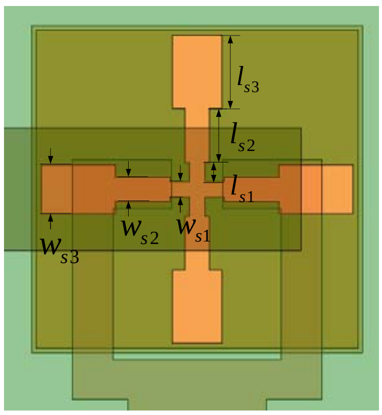

Figure 4. Cross shape slot in ground plane

Table 1. SPA design parameters

Parameter	l_r	l_p	l_{v1}	l_{v2}	l_{h1}	l_{h2}	l_{h3}	l_{h4}	l_{h5}	w_{v1}	w_{v2}	w_{h1}	w_{h2}	w_{h3}	w_{h4}
Dimension /mm	6.70	6.50	3.95	7.00	2.75	1.80	4.90	5.04	2.00	1.00	2.50	1.55	2.80	0.82	1.00

Table 2. Cross-shape aperture parameters

Parameter	l_{s1}	l_{s2}	l_{s3}	w_{s1}	w_{s2}	w_{s2}
Dimension /mm	1.10	1.10	1.50	0.10	0.18	0.50

3. Results and Discussion

A prototype with geometry parameters shown in Table 1 and Table 2 was tested for refection coefficient, port isolation, and radiation patterns using Agilent E8363B vector network analyzer. Photographs of SPA and different layers of SPA are shown in Figure 5 and Figure 6.

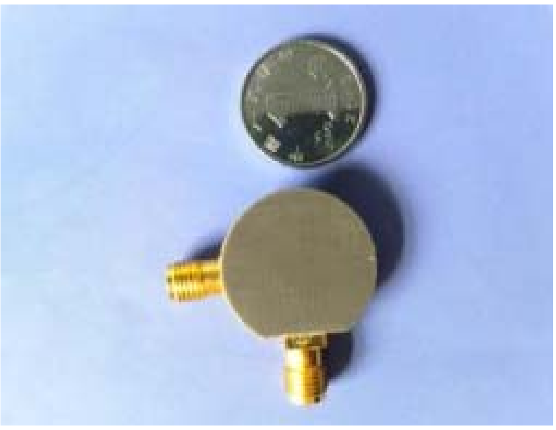

Figure 5. Assembly view of SPA prototype

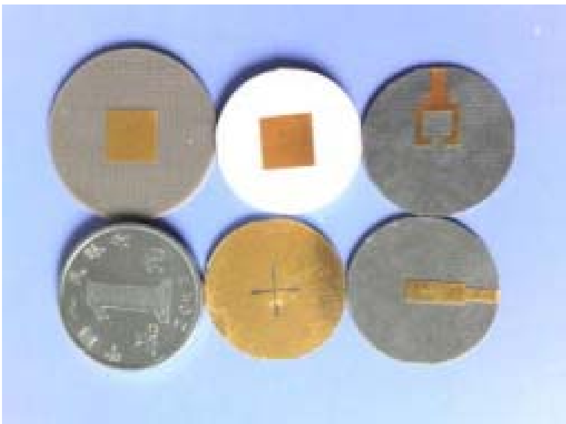

Figure 6. Different layer view of SPA prototype

Theoretical (simulation results from Ansoft HFSS) and measured results of refection coefficient against variable frequency for both ports are shown in Figure 7 and Figure 8. Measured results of refection coefficient for both ports show good accordance with each other. It can be seen in Figure 7 the reflection coefficient is -20dB at frequency of 9.6 GHz for port 1, -28dB at frequency of 9.2 GHz for port 2 in Figure 8, and better than -10dB for both ports in frequency range from 8.4 GHz to 12 GHz (a bandwidth of 35.3%). It is observed that a reasonable agreement is obtained between theoretical and measured results which are even better. The measured isolation shown in Figure 9 between two orthogonal ports is better than 30dB from 8GHz to 12GHz which is slightly worse than simulation results which may be caused by assemble error.

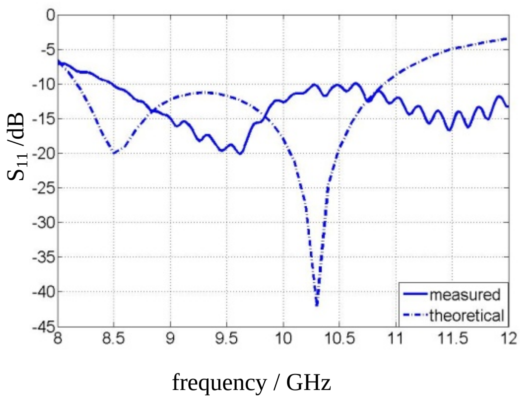

Figure 7. Theoretical and measured results of refection coefficient at port V

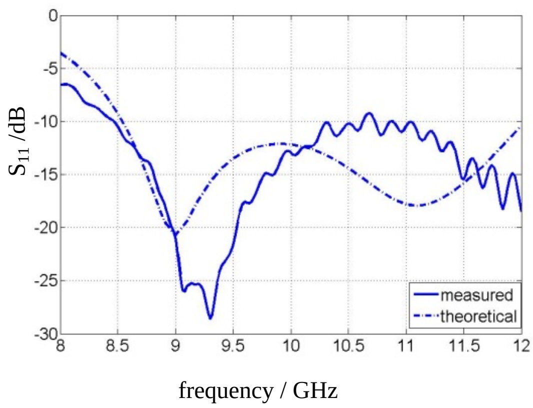

Figure 8. Theoretical and measured results of refection coefficient at port H

Compare between antenna in [10] and proposed in this paper is shown in Table 3. Impedence bandwidth with reflection coefficient below -10dB is almost the same. Also wide range of high isoaltion between two ports is observed in this paper. High isolation is important for dual-linear polarized antenna to reduce cross polarization. Although similar measure results are obtained in [10] and in this paper. The feeding structure proposed in this paper is more simple and easy to realize. The asymmetrical microstrip lines used as different linear polarization excitation lead to a novel feeding way without rigidly symmetrical feeding structure. Measure results of reflection coefficient and isolation prove that asymmetrical way proposed in this paper can also provide broad bandwidth and high isolation in dual-linear polarized antenna design.

Table 3. Comparison between antenna in [10] and this paper

	Impedence bandwidth (reflection coefficient<-10dB)	Isolation between two ports (isolation>30dB)
Antenna in [10]	35.8%	whole working band
Antenna in this paper	35.3%	whole working band

From 8GHz to 12GHz, the SPA gain shown in Figure 10 is measured for both polarizations every 500MHz. SPA gain is higher than 6dBi over the frequency range from 9GHz to 12GHz for both ports. The relative lower SPA gain at lower working frequency can be attributed to the higher return loss than other working frequency.

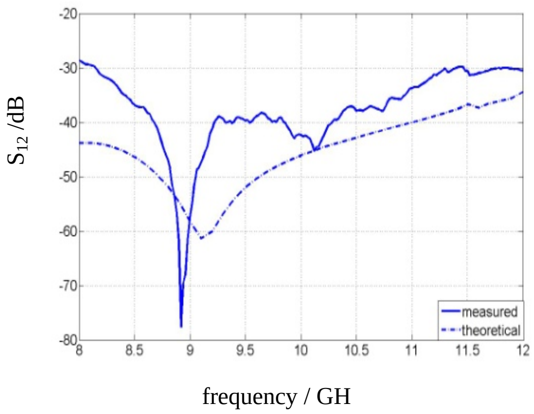

Figure 9. Theoretical and measured results of isolation between port V and port H

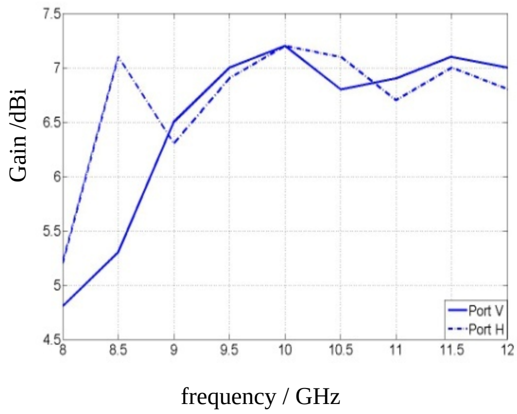

Figure 10. Measured gain of antenna for both ports

Normalized radiation patterns at 12GHz of E plane and H plane for both port V and port H (shown in Figure 2) are presented in Figure 11 and Figure 12. The 3dB beam width of both ports is wider than 60°. For port V, coplanar polarization is 20dB higher than cross polarization. For port H the cross polarization of E plane is about 15dB lower than coplanar polarization which is slight higher than that of H plane. Direct coupling from microstrip line 2 to stacked patches may cause this decreased cross-polarization of E plane at port V.

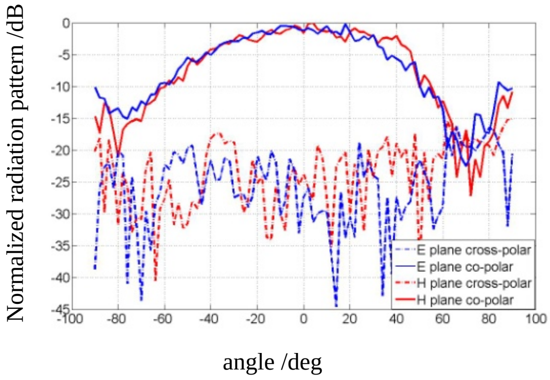

Figure 11. Measured co-polarization and cross-polarization at port V

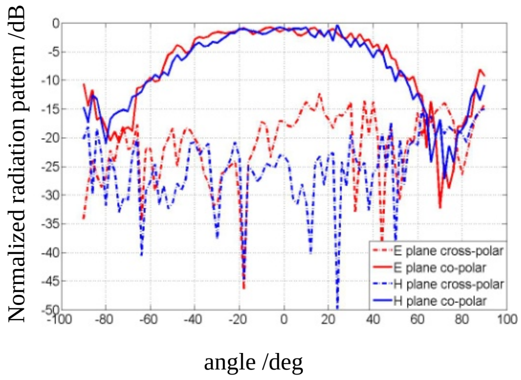

Figure 12. Measured co-polarization and cross-polarization at port H

4. Conclusion

A wideband dual-linear polarized stacked patch antenna is presented in this letter. By applying aperture coupling and stacked patches technique into antenna's design, wideband dual-linear polarization is realized. Asymmetry feeding structure (U-shape microstrip line and typical microstrip line) in different layer allows a high isolation between two orthogonal ports. This feeding technique makes it easier to realized dual polarization and can also be used for circular polarization by introducing a power divider. The stair case of cross-slot in ground plane is optimized to reduce return loss and improve the isolation between port V and port H. Measured wide impendence bandwidth and high isolation are available which agree well with simulation results. According to measurement, measured antenna gain and radiation pattern with co-polarization and cross polarization also have a good performance. The asymmetry feeding structure is effective in aperture coupling SPA design. The following investigation will be focus on how to get a unidirectional antenna beam with low profile and higher front to back ratio (F/B). This asymmetry feeding way lead to a compact structure of this antenna which can be used for dual-polarized array antenna.

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