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A Low Profile Dual Polarized Slot Coupled Patch Antenna

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***Abstract*—**A low profile, dual polarized, slot coupled patch antenna is designed and developed in this paper. The antenna has a measured bandwidth of 17.2% for return loss > 15 dB and pair ports isolation >23 dB. The gain of the antenna is over 10 dBi and the half power beam widths (HPBW) of the antenna are 80±3^o in the horizontal plane and 39±2^o in the vertical plane. The cross polarization discrimination (XPD) is less than 20 dB in HPBW. Within the operating band, the performances of good impedance match, high ports isolation, low cross polarization, and stable radiation patterns are achieved.

***Keywords*—**Dual polarized, patch antenna, slot coupled, base station antenna.

I. Introduction

SLANT ±45^o dual polarized antenna is widely used in modern communication systems due to its excellent performance in increasing the capacity of communication system [1]-[3]. Antennas with low profile are highly desired since miniaturization has been the leading trend [4]. Patch antennas have been widely used in modern communication systems due to the easy fabrication, low cost, low profile and high integration. A common feeding technique for patch antennas is based on slot coupling, where micro-strip feeding lines are coupled to the radiating driver patches through slots in metallic ground [5]-[7]. Symmetrical feeding lines are proposed with respect to the geometrical and electrical symmetry, which are also advantageous in improving ports isolation and radiation XPD performance [8], [9]. Two feeding lines are usually needed to get a dual polarized antenna. To avoid overlapping between the two lines, an air bridge is taken in [10]. The back ground effects on the performance of impedance and radiation are studied in [11], [12]. The studies show that the slot radiates both in the patch direction and in the back direction which results in low gain and low front to back ratio. Moreover, the metallic ground plane where slots are realized prevents the spurious radiation from the feed network and then reduces the amplitude of the cross polarization components. To design a usable antenna element, a stable reflector must be placed behind the slot coupled ground plane [13].

In this communication, a slot coupled patch antenna with substrate integrated waveguide (SIW) back cavity and metallic ground wall is proposed. The SIW back cavity is designed to construct a stable metallic back reflector and the metallic ground wall is designed to improve the radiation performance of the antenna. Based on the proposed design approach, the T/R modules and active devices can be mounted directly on the back of the antenna. To validate the proposed technique, a C-band slant ±45^o polarized 64 ports MIMO antenna is fabricated and tested.

This paper is organized as follows. In Section II, the structure of the proposed antenna configuration and detailed dimensions are described. Section III deals with measured results to validate the analysis. Finally, some conclusions are drawn in Section IV.

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II. Antenna Configuration and Design

The geometry of the proposed antenna and array is illustrated in Figs. 1 and 2. The prototype contains basis element of 2 x 1 patch antenna and totally 64 ports MIMO antenna array. Detail constructions of the antenna are shown in Fig. 3.

A. Antenna Element

Fig. 1 shows the configuration and details of the proposed antenna element. The structure consists of four main building blocks as follows:

1) Cross Slot Ground and SIW Back Cavity

The substrate used here is a 60 mm thick F4B-265 with basic electrical properties of Dk=2.65, Df =0.001 at C band. As Fig. 1 (a) shows, the bottom layer-3, which is printed on the bottom of PCB-2, is a back reflect ground. The middle layer-2, which is printed on the top of PCB2, is a metallic ground with corroded cross slots. The length and width of the cross slots are 29 mm and 0.7 mm, respectively. Metallic through holes around the square combined with the printed metallic layer-2 and layer-3 construct a square SIW back cavity. The optimized side length of the cavity is 29 mm.

2) Feeding Network

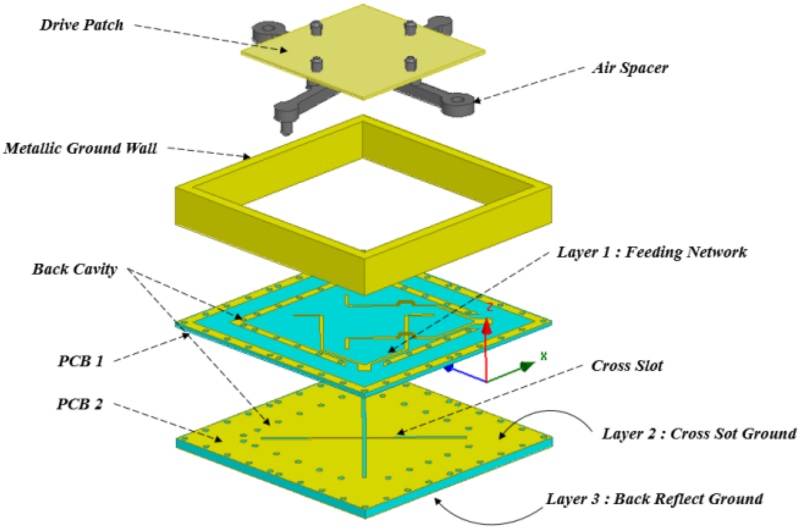
PCB-1 is a 30 mm thick F4B-265. On the top layer-1, two symmetrical dual-feed microstrip lines are printed 0.035 mm thick. Air bridges are designed to avoid the cross connecting of feeding arms. Details of the air bridges are shown in Fig. 1 (c). The arm, which is not cross connecting with others, is also cut off and bonding by an air bridge at the same place with the paired one to keep the feeding balance. The air bridge structure on top layer-1 can avoid the complicated manufacture process of the PCB and reduce the uncertainty bring by the slot on the bottom ground.

3) Metallic Ground Wall

Notice that the metallic ground wall should be large enough to avoid the cutoff at lower frequency. Meanwhile it should be lower than the direct patch to keep the radiation efficiency of the antenna. Also, the metallic ground wall should hard enough to keep the whole PCB and antenna in shape. Here, a 2 mm thick metallic wall made of aluminum is designed. The outer side length of the wall is 44 mm which is approximately 1/2λ length at 3.4 GHz.

4) Direct Patch

A group of aluminum direct patches with side length range from 28.4~29.4 mm with step of 0.2 mm are made for the benefit of tuning in MIMO antenna array. Quasi-cross plastic air spacers shown in Fig. 1 (a) are fabricated to support the patches.



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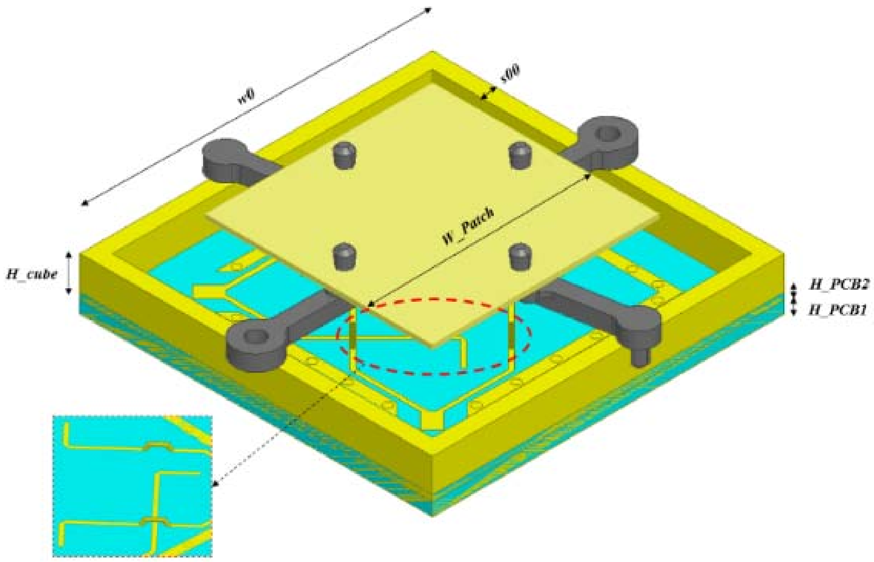

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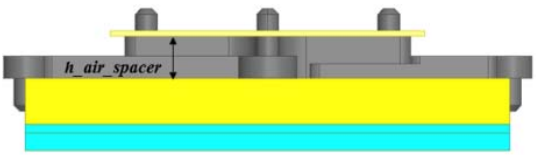

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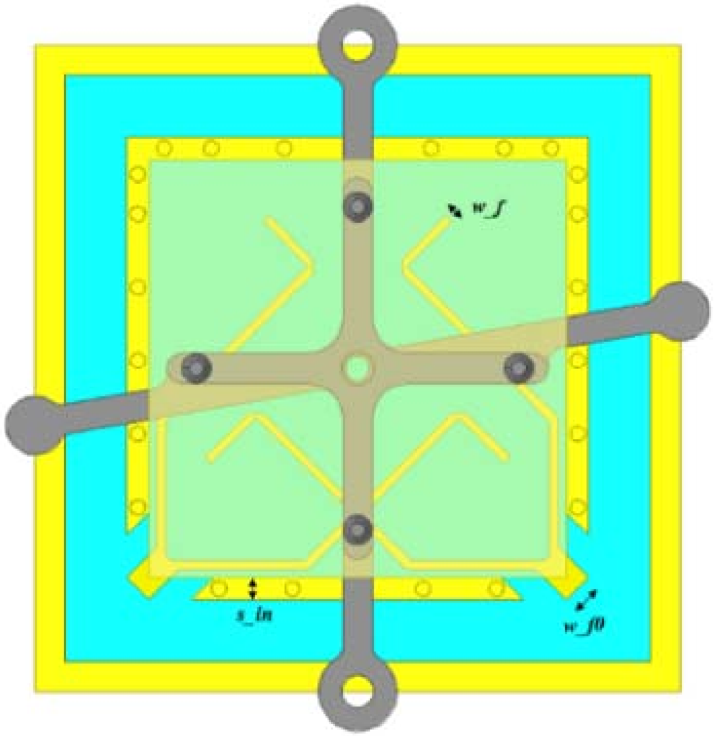


(d)

Fig. 1 Configuration of the antenna element. (a) Exploded 3D view of the antenna. (b) 3D View of the antenna. (c) Side View of the antenna. (d) Top View of the antenna

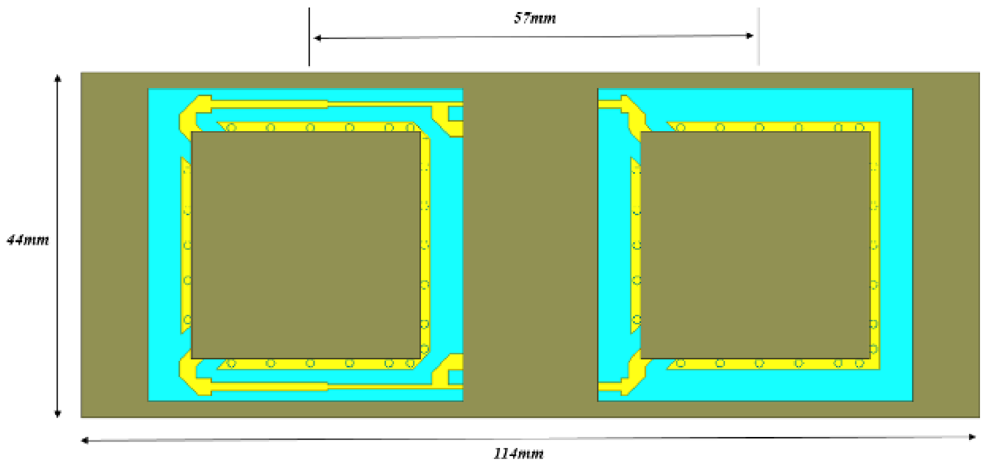


Fig. 2 Top View of the 2 x 1 antenna element

B. 2 x 1 Element and 64 Ports Antenna Array Design

The azimuth spacing of the antenna array is set to provide maximum gain with minimum coupling and the least beam correlation. While 44 mm gives optimum performance with approximately 1/2λ spacing at 3.4 GHz. Elements are paired in elevation which give a total of 64 ports in an 8x8 array. Elevation spacing is set at 57 mm to allow 0~12^{o} scan range in elevation without acceptable grating lobes and side lobes. In this communication, a fixed 6^{o} down-tilt antenna is designed.

BMA connectors, which are blind mate and PCB mounted through wall RF connectors, are taken for the convenient of installation with TR modules. In order to further more reduce the total thickness of the antenna, blind holes are drilled on PCB-2. The connectors can be assembled in the blind holes, and thus, the antenna reduces the total thickness of PCB-2. Details of the antenna parameters are shown in Table I.

TABLE I
DETAIL DIMENSIONS OF THE ANTENNA

Parameters	Values[mm]	Parameters	Parameters
H_PCB1	60mil	w_cavity	29
H_PCB2	30mil	pin_r	20mil
H_Cube	4.2	pin_span	5
H_air_spacer	3.8	slot_length	29
w_patch	29	T_patch	0.5
s00	2	w_f0	2.1
s_in	1.5	w00	44
bridge_length	2.8	slot_width	0.7

III. EXPERIMENTAL RESULTS

For the verification of the design, a 64 ports MIMO antenna array is fabricated and measured. As shown in Fig. 3. The 64 ports antenna array is made of four separate 16 ports antenna arrays, and each 16 ports antenna contains 2 x 8 dual polarized antennas. The total dimension of the 64 ports antenna array is 362 mm x 466 mm x 8 mm.

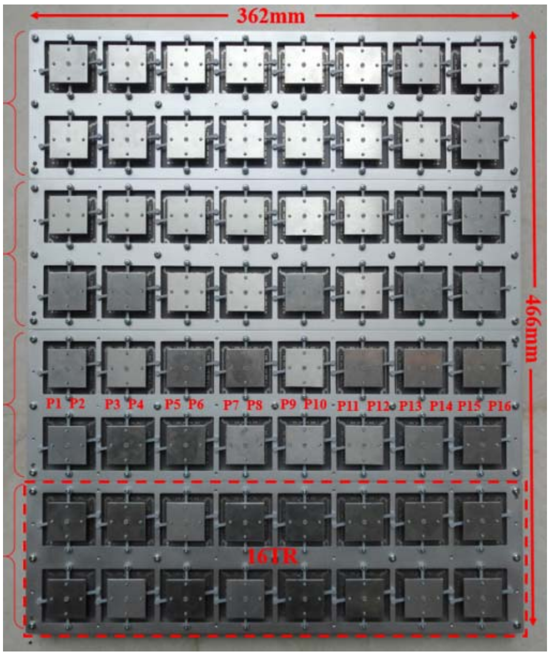


Fig. 3 Fabricated 64 RF ports antenna array

A. S-Parameter

The measured results shows that the impedance bandwidth of all ports in the 64 TR array is greater than 17.2% with return loss >15 dB. In the operating band 3.4~3.6 GHz, return loss >20 dB can be obtained in Fig. 4. For the pair ports at the edge of the array, the measured isolations are greater than 29 dB, as shown in Fig. 5; for the pairs ports in the center of the array, the measured isolations have a degree of decline, but still greater than 23 dB. The measurement S-parameter results show that in a compact MIMO array, the good impedance can improve the system quality and the high isolation can increase the system capacity. Details of the S-Parameters information of a 16 TR antenna array are depicted in Table II.

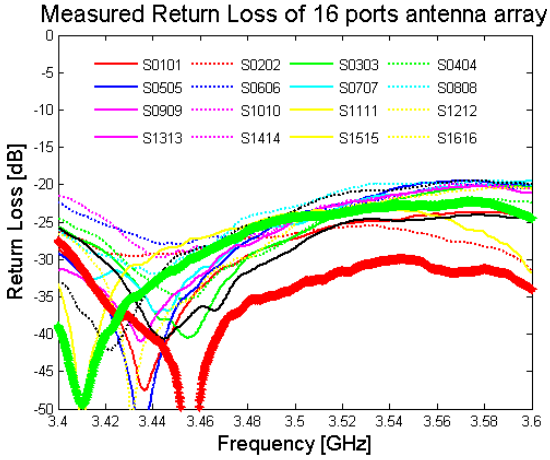


Fig. 4 Measured return loss of 16 ports antenna array

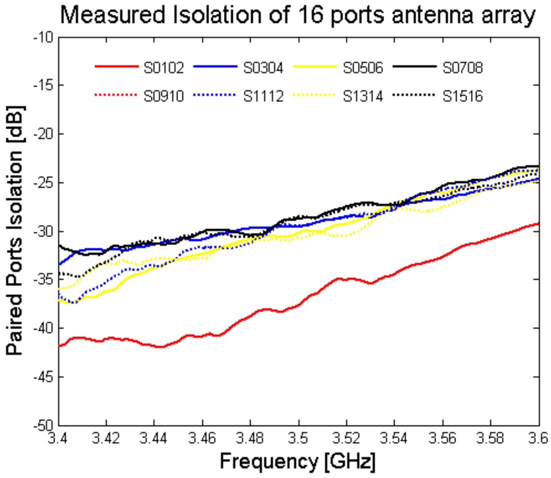


Fig. 5 Measured isolation of 16 ports antenna array

TABLE II
MEASURED S-PARAMETERS OF THE 16 PORTS ANTENNA ARRAY

Ports/Parameters	Return Loss [dB]	Isolation [dB]
Port 1	-23.7	-29.3
Port 2	-25.4	
Port 3	-20.1	-24.7
Port 4	-21.7	
Port 5	-19.5	-23.7
Port 6	-20.0	
Port 7	-19.5	-23.4
Port 8	-19.5	
Port 9	-20.3	-23.8
Port 10	-20.0	
Port 11	-23.3	-24.8
Port 12	-20.4	
Port 13	-24.0	-24.1
Port 14	-19.5	
Port 15	-27.6	-28.5
Port 16	-22.3	

**The recorded figures in the table are the maximum measured results in the band, which usually represent the worst case in the operating bands.*

IV. Radiation Performance

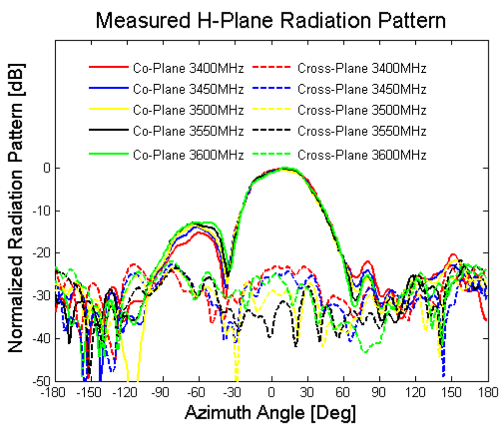
Measurement results show that the antennas have radiation gains of 10.0 dBi to 10.7 dBi. The detailed measured E-plane and H-plane radiation patterns of the antenna from 3.4 GHz to 3.6 GHz with step 50 MHz are shown in Fig. 6. It can be seen that the HPBW of the antennas are 77~83° in H-plane and 37~41° in E-plane. In the H-plane, the XPDs are less than 30 dB at peak, less than 20 dB within +/-30°, less than 10 dB at +/-60°; while in the E-plane, the XPDs are less than 30 dB at peak, less than 20 dB within +/-20°. Details of the radiation performance of are depicted in Table III.

TABLE III
Measured Gain and HPBW of the 16 Ports Antenna Array

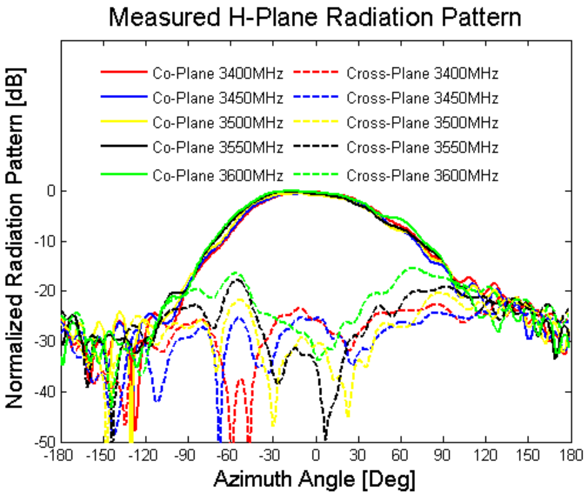
Frequency (MHz)	Parameters	Measured Gain and HPBW (dBi/ degree) Port 1		Port 2	
3400	Gain	10.03		10.22	
	HPBW	H-Plane	V-Plane	H-Plane	V-Plane
		81.9	38.9	77.9	39.6
3450	Gain	10.01		9.99	
	HPBW	H-Plane	V-Plane	H-Plane	V-Plane
		80.9	40.4	78.4	39.7
3500	Gain	10.14		10.10	
	HPBW	H-Plane	V-Plane	H-Plane	V-Plane
		77.8	38.8	79.3	39.2
3550	Gain	10.28		10.24	
	HPBW	H-Plane	V-Plane	H-Plane	V-Plane
		79.8	38.4	79.7	39.5
3600	Gain	10.18		10.07	
	HPBW	H-Plane	V-Plane	H-Plane	V-Plane
		82.5	38.81	83.2	40.1

V. Conclusion

In this paper, we have proposed a wideband dual polarized slot coupled patch antenna, based on the propose technique, a 64 ports antenna array is fabricated and measured. The antenna array, with a total size of 362 mm x 466 mm x 8.4 mm, covers the band of 3.3~3.9 GHz with Sii <-15dB, Sij <-23dB, and gains more than 10 dBi. This result shows that the antenna is a very good candidate for the modern, massive MIMO communications.



(a)



(b)

Fig. 6 Measured E-Plane and H-Plane Radiation Pattern

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