Wang-Shaped Patch Antenna Excited by H-Plane Oriented Wideband Feed-Networks

Chi-Ho Wong[1], #Kwok L. Chung[1], Wai-Yip Tam[1] and Sarawuth Chaimool[2]

[1]Department of Electronic and Information Engineering, Hong Kong Polytechnic University
Hung Hom, Kowloon, Hong Kong SAR, PRC
Email: klchung@ieee.org
[2]Electrical Engineering, King Mongkut's University of Technology North Bangkok,
1518 Pibulsongkram Rd. Bangsue, Bangkok 10800, Thailand
E-mail: sarawuth@kmutnb.ac.th

1. Introduction

Over decades, impedance/return-loss bandwidth broadening of microstrip patch antennas has long been an essential objective in antenna society. Geometry complexity and cost effectiveness of many novel designs are the common yet essential trade-offs. Amongst the known techniques, the singly-fed slot-loaded single patch antennas with air substrate were the most simple and cost-effective designs [1]-[2]. When a U-slot [1] or a pair of parallel slots [3]-[4] is added onto a rectangular patch, additional current paths on the patch are extended so that nearby resonant modes can be generated. By merging of these adjacent resonant modes, a large 10-dB return-loss bandwidth (RLBW) of ~30% can be achieved [1]-[4]. However, both the geometries of U-slotted and E-shaped patches are inherently asymmetric. While a larger RLBW demands a higher antenna height, higher-order modes and probe radiation destroy radiation patterns and cause high cross-polar (x-pol) levels [5]-[6]. These, in turn, result in small pattern bandwidth and/or polarization bandwidth [5] in spite of the return-loss bandwidth was up to the order of 40-50% [7]. By the invention of Wang-shaped patch [8], which is differentially fed by a pair of mirrored L-probes, excited by an E-plane oriented wideband feed-network, the cross-polar levels have been suppressed below -20 dB over a bandwidth of 1.7 to 2.5 GHz. To avoid spurious radiation from the microstrip-lines [9] that interferes with co-polarization, feed networks are usually fabricated and printed below the antenna ground-plane. However, additional system ground-plane is required to be mounted at a distance from the feed-network, or otherwise, spurious radiation may interfere with the associated electronic circuits that share the same ground-plane. This paper illustrates the spurious effects of an H-plane oriented wideband feed-network, placed above and below the ground-plane, respectively. Impedance matching, radiation patterns, cross-polar levels, maximum gain and efficiency of the Wang-shaped antennas are all compared.

2. Description of Antennas

The geometries of the Wang-shaped patch antenna designs (Antenna A and Antenna B) in top (*xy*-plane) and side (*xz*-plane) views with the layout of a differential feed-network are depicted in Figure 1. Antenna A has its wideband balun mounted above the grounded substrate whereas that of Antenna B is fabricated below the ground-plane. By combining two mirrored E-shaped patches, the resultant patch resembles the Chinese character "王" (pronounced as Wang), hence the name Wang-shaped patch antenna. Wang patch is symmetrical with respect to both the *x* and *y* axes and is mounted over a ground plane (using foam) at a height of H. A pair of mirrored L-probes is fed by anti-phase currents by means of differential length of the 100-Ω microstrip line from the wideband feed-network. This is used to suppress higher-order mode currents flowing in undesirable directions as well as the cancellation of probes radiation in azimuth direction. A Rogers RO3003 dielectric substrate (ε_r=3, tanδ= 0.0013) with 1.52 mm thickness is used for fabricating the wideband feed-network. The dimensions of the patch, slots and feed probes are listed in Table I. In this study, both antennas have the same ground-plane size of 150 mm × 150 mm in order to facilitate a fair comparison.

3. Results and Discussion

Figure 2 depicts both the simulated and measured return-losses versus frequency, with radiation patterns at essential frequencies of 1.7 GHz, 2.1 GHz and 2.4 GHz for Antennas A and B, respectively. As can be seen, both antennas have the similar measured 10-dB RLBW of 1.6x to 2.4x GHz while Antenna A having a better impedance matching. From those selected patterns (without examining others), the cross-polar levels are found to be suppressed below -20 dB in both E- and H-plane while Antenna A having a slight offset on its main-beams. However, further examining other frequencies using the cross-polar level vs. frequency plot as shown in Figure 3, the H-plane cross-polar level of Antenna A is increased to around -18 dB at 1.8 and 1.9 GHz. These high cross-polar levels are mainly due to spurious radiation from its feed-network.

From the Figure 4, the average gain of Antenna B is measured as 8.4 dBi, about 1 dB higher than antenna A within the bandwidth of 1.7-2.4 GHz. Meanwhile, the measured average efficiency of Antenna B is also ~10% higher than that of Antenna A. These can be explained by the small difference in antenna heights, 30 vs. 26.5 mm (see Table I), in addition to the different placements of feed-network, that is, the effect of spurious radiation from the feed-network. As Antenna A has the dielectric slab (RO3003) faced to the Wang-patch at a higher height, its fringing field is stronger than Antenna B, and thereby Antenna A stores more energy but has less radiation intensity than Antenna B. As a result, Antenna A has a weaker broadside emission and lower radiation efficiency. The photographs of both antenna prototypes are shown in Figure 5.

4. Conclusion

This paper illustrates the spurious radiation of a wideband feed-network placed above and below the antenna ground-plane. Two identical Wang-shaped patch antennas excited by using H-plane oriented feed-network, with small difference on their antenna heights and feed-probe lengths. As expected, the one with wideband balun arranged below ground-plane (Antenna B) results a better cross-polarisation suppression whereas wideband balun placed above ground-plane (Antenna A) having a better impedance matching. Antenna B has good isolation against cross-polarization due to the main feed-line currents, flowing in H-plane direction. Interestingly, Antenna B exhibits a higher antenna gain and a higher efficiency. However, both antennas are found to have the similar 10-dB return-loss bandwidths.

Acknowledgment

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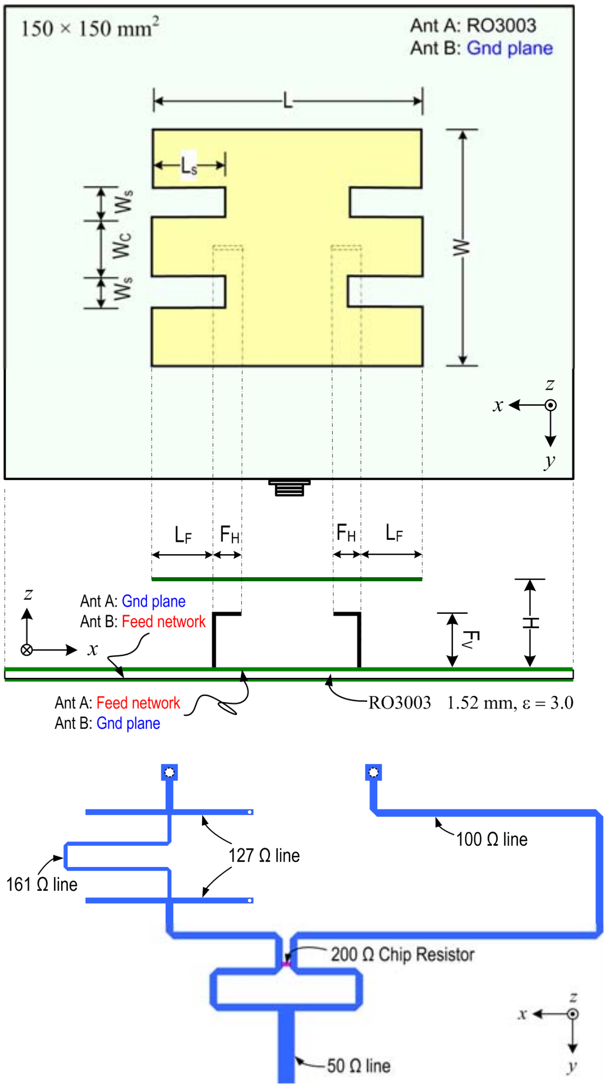


Figure 1 Geometry of Wang-shaped patch antenna with H-plane oriented wideband feed network.

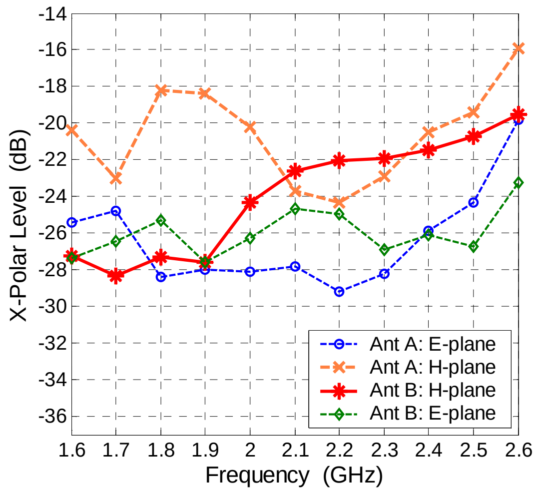


Figure 3 Measured cross-polar levels.

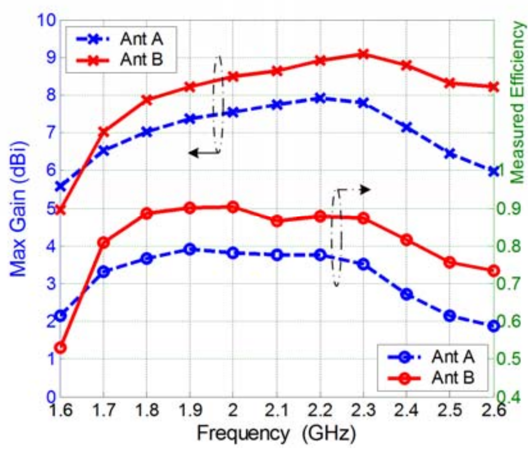


Figure 4 Measured gain and efficiency.

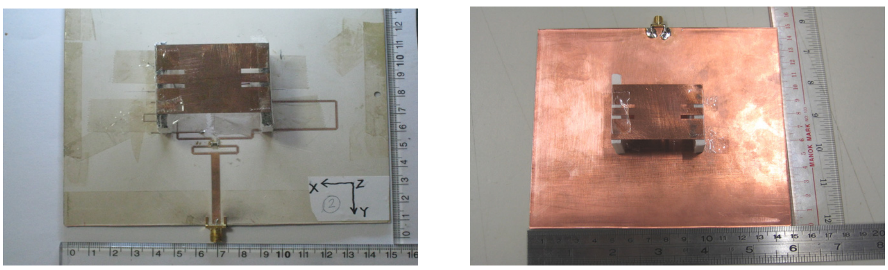
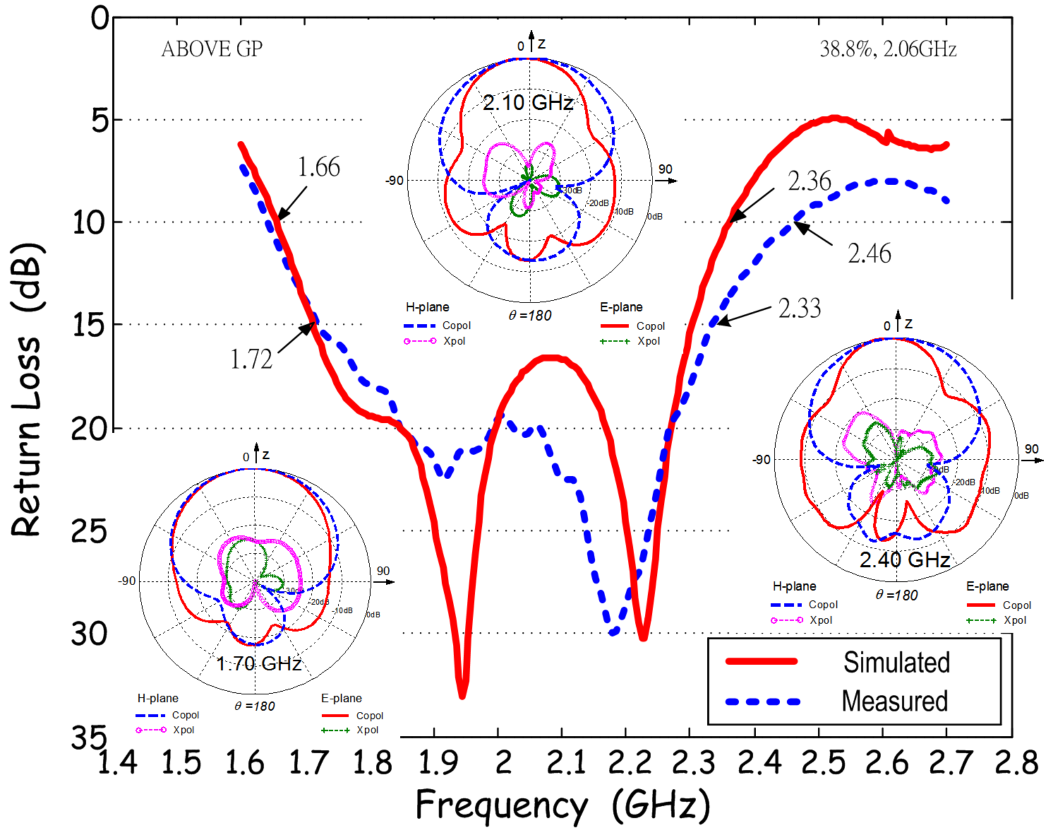


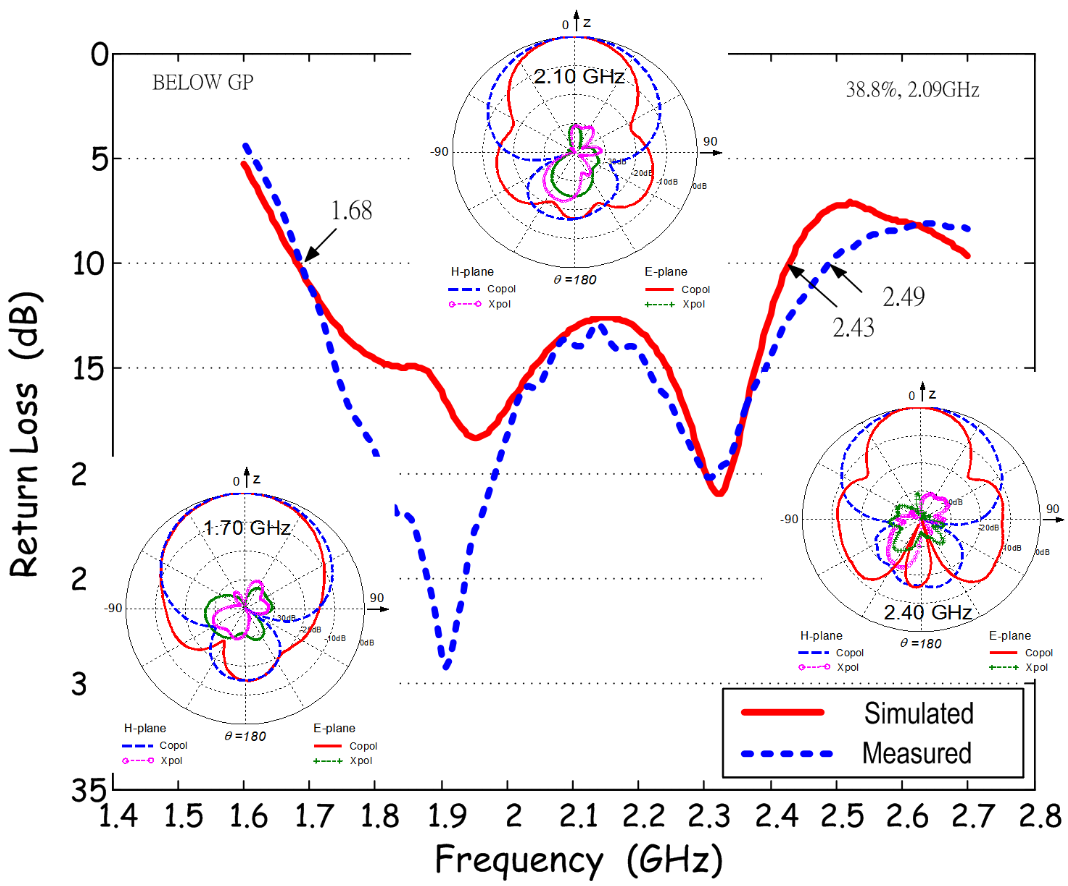
Figure 5 Photographs of Antenna A (left) and Antenna B (right).

Table I

	L	W	Ls	L_F	W_S	W_C	F_H	F_V	H	Unit
Ant. A	50	37.5	12.5	7.5	2.5	5	10.5	24.8	30	mm
Ant. B	50	37.5	12.5	7.5	2.5	5	11.5	23.3	26.5	mm



Antenna A



Antenna B

Figure 2 Simulated and measured return-losses with selected radiation patterns.