A Small Ultra-Wideband Folded Half E-shaped patch antenna*

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Abstract - A novel fourth wavelength folded Ultra-wideband microstrip antenna is presented in this paper. This patch antenna is combined half structure technique and folded patch technique to create a Ultra-wide impedance broadband patch antenna with small geometric size. It is employed the same parameters as the folded E-shaped quarter-wave patch except with half the area and bandwidth of 60.9% is obtained. It is shown that the impedance bandwidths, radiation patterns, radiation efficiencies and gains of the half structures are comparable to the corresponding full structures.

Index Terms - Small size, Ultra-wideband, microstrip antenna.

I . Introduction

The Microstrip patch antennas (MPA) have the advantages compared to the traditional microwave antennas such as low profile, light weight low cost. However, it inherits narrow bandwidth and relative large size in microwave frequency range. The ultra-wideband (UWB) frequency ranges from 3.10 GHz to 10.6GHz as per the specifications of Federal Communications Commission (FCC). UWB communication system is attracting more and more attention because of its advantages such as low power consumption, high data transmission rate as in the multimedia communications and low interference to other systems etc. It is possible that UWB will become a popular next-generation, short-range wireless connection technology. Meanwhile, the small size communication system is always desirable. In many applications the requirements on both bandwidth and physical size are quite stringent [1]. One of the wideband designs is the use of u-slot patch [2]. The shorting wall and the shorting pin are two common employed techniques in designing small patch antennas. Some techniques have been proposed including a new technique to obtain two closely staggered resonant modes to achieve a wide impedance bandwidth using two unequal arms [3], the employment of a thick substrate with a low dielectric constant patch [4], the use of multiple resonators [5] and the broadband u-slot patch with a shorting wall [6, 7] or a shorting pin [7, 8]. A novel technique that improves the performance of a conventional quarter-wave patch antenna is proposed in [9][10]. It is used folded patch to enlarge the impedance bandwidth. The same technique is also applicable to dual-band and wideband applications [11,12], albeit more complicated geometrical configurations. Another size reduction technique is proposed in [13]. The size of a u-slot patch antenna is halved by removing half of the patch area along the line of symmetry. It was found that the performances of the half u-slot patch antenna are comparable to the full u-slot patch antenna. The shorting wall and shorting pin techniques also has been applied in half u-slot patch antennas [14, 15]. Another bandwidth-enhancing technique is the use of E-shaped patch. It is reported that the impedance bandwidths of a conventional E-shaped patch antenna and a stacked E-shaped patch antenna with the use of a circular washer are 32.3% [16] and 44.9% [17], respectively.

In this paper, based on the idea of folded patch antenna [10] and halving the u-slot antenna [13], a new kind of broadband small antenna is proposed. The structure of proposed patch antenna is employed the same parameters as the folded E-shaped quarter-wave patch proposed in [10] except with half the area. By both simulation and experimental studies, it is shown that the impedance bandwidth, radiation pattern and gain of this antenna are comparable to the full folded E-slot antenna. Radiation patterns are stable across the matching band.

II . Modeling Structure

It is known from paper [4] that increasing the thickness of the substrate can lower the Q-factor leaky resonator and it will increase the impedance bandwidth. However, the thicker the substrate of the antenna, the longer the coaxial probe will be used, and thus, more probe inductance will be introduced, which limits the impedance bandwidth. Using folded patch can solve the problem. In addition, for some antenna structures, such as the rectangular with U-slot and E-shaped, when viewed from the top, a double resonance can be easily obtained. These are the main reasons for achieving a wide impedance bandwidth for these patch antennas. Fig. 1(a) shows the full size of the quarter wavelength folded E-shaped patch antenna and fig. 1(b) shows the prototype of the proposed patch antenna. The half structure technique was applied to the quarter wavelength folded E-shaped patch antenna. Due to the symmetry of the current distribution, removing half of the patch does not apparently alter the current paths and the resonant behaviour. The proposed antenna is employed same parameters as the full one except using W_H instead of W_1. Three antennas are reported in [10], and we constructed halved antenna model to verify the design procedure. The antennas are designed to operating at about

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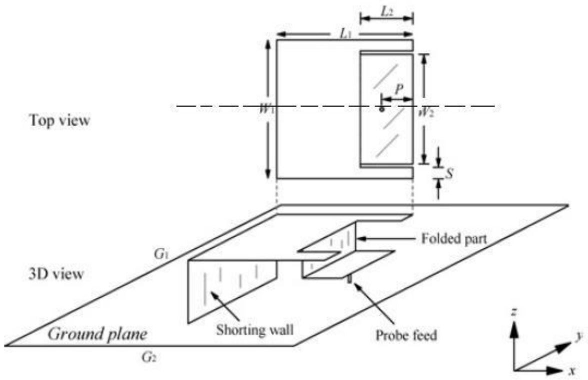
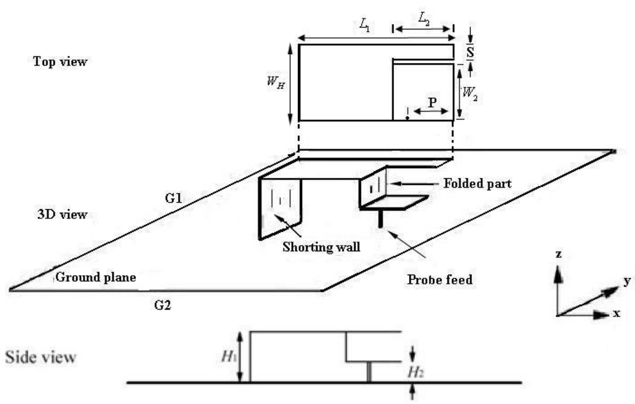
6GHz. The entire radiating element is centered on top of a square ground plane with size of 40mm╳40mm. A shorting wall with the same width as the upper patch is connected to the ground plane, which is mainly used to reduce the overall size of the antenna.

The radiating patch including the shorting wall is made of 0.3-mm copper sheet. As the substrate of the whole antenna is air, the antenna is supported by the coaxial probe and the shorting wall. The overall height (H_1) of the proposed antenna is higher than the length of the probe (H_2).



(a) Full structure



(b) Half structure

Fig.1. Geometries of the quarter wavelength E-shaped patch antennas

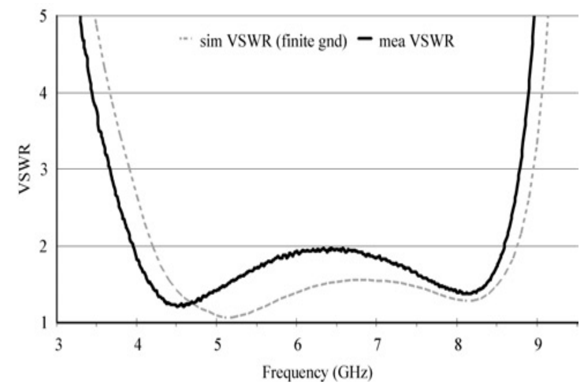
Therefore a thicker substrate is introduced without increasing the probe inductance. This helps widen the impedance bandwidth of the antenna significantly. The one arm of the half E-shaped patch antenna presented on the upper patch play an important role in producing a double-resonance. The specific dimensions of the antenna are shown in Table I.

TABLE I Dimensions of Antenna A and Antenna B (units in mm).

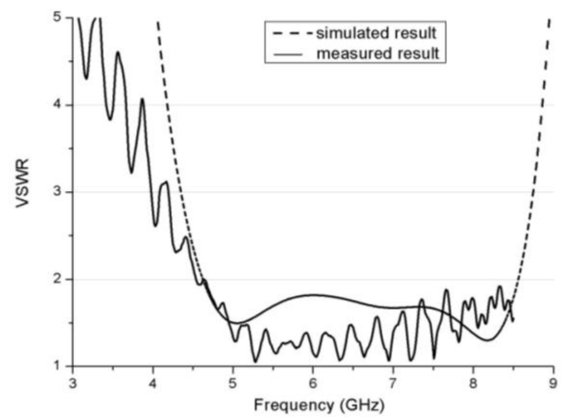
L_1	L_2	H_1	H_2	W_H	W_2	P	S	G_1	G_2
15	6	7	2.5	7.5	5.5	5	1.5	40	40

III. Numerical Simulation and Experimental Results

The proposed antenna is measured by Agilent HP E5071C Network Analyser with a range of 9 KHz-8.5GHz. Fig. 2(a) is the simulated and measured results of the voltage standing wave ratio (VSWR) of the full structure antenna. The simulation and measured bandwidths (VSWR≤2) are 68.2% from 4.3 GHz to 8.75 GHz and 73.8% from 3.96GHz to 8.59 GHz. The simulated and measured impedance bandwidths (VSWR≤2) of the proposed antenna are given in Fig. 2(b). It is noted that the antenna may operate from 4.53 to over 8.5 GHz (VSWR≤2) with a bandwidth of 60.9% which agrees well with the simulation using a finite ground plane model. The difference between simulated and measured results may be mainly resulted by manufacture and instrument precision error.



(a) Antenna of full structure



(b) Antenna of half structure

Fig.2. the VSWR results of the Antenna 1 and Antenna A

Fig.3 shows the simulated results of proposed antenna A at 4.53, 6.27 and 8.56 GHz in xz and yz planes. They are similar to the radiation patterns of full structure. As with most small antennas with shorting pin and shorting wall, the cross polarization levels are considerably higher than conventional patch antennas. Although the operating frequency band is 60%, the radiation patterns of the proposed antenna do not change drastically over the frequency band.

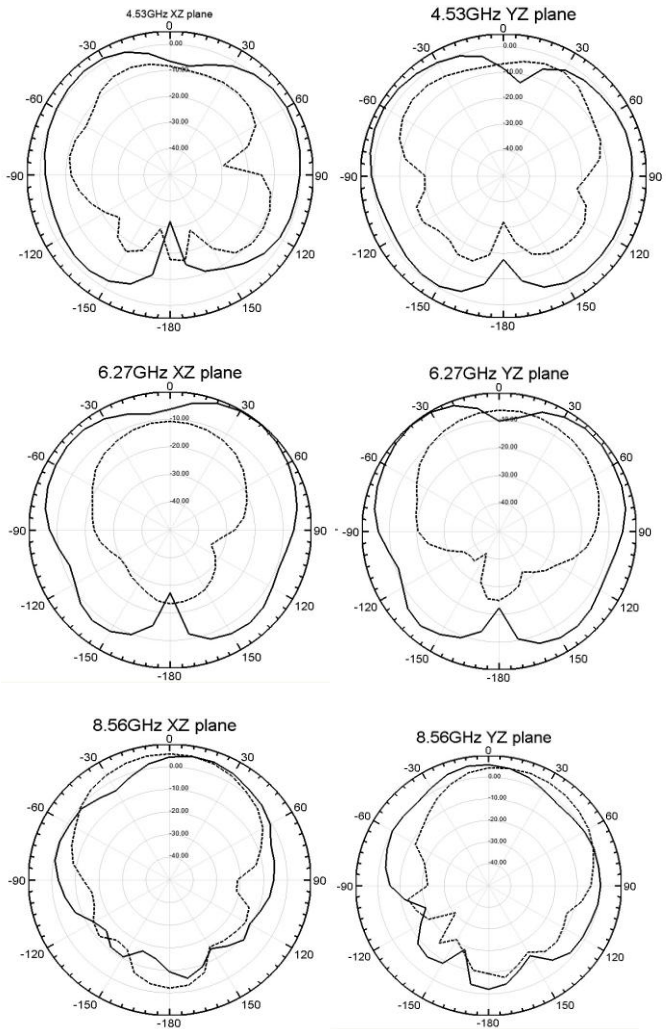


Fig.3. The radiation patterns — E_θ ··· E_Ψ

The simulated gain of the proposed antenna is given in Fig.4. The total Gain doesn't change roughly with a peak gain of almost 7dB. The average Gain is about 5.5dB.

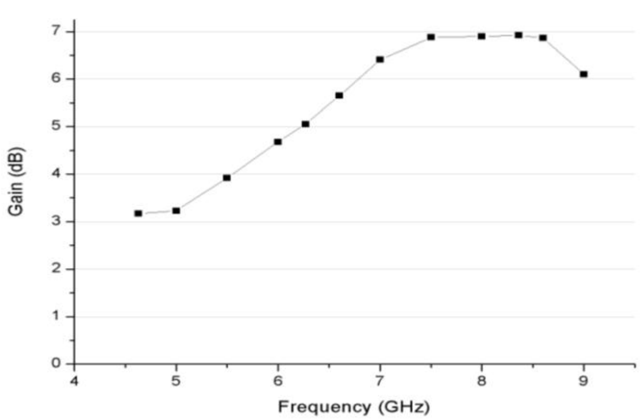


Fig.4. The total Gain of antennas

Table.II is comparison between the full and half structure antenna. In table.2, the symbol λ_0 is the free space wavelength at the centre frequency of the each antenna. Compared all those dates, it can be seen through halving the structure of original antenna, the antenna size is reduced more than 45% and comparable antenna performance is remained.

TABLE II Comparison between the Full and Half Structure (unit in mm)

	Antenna	
	Full	Half
Length	15(0.314λ_0)	15(0.326λ_0)
Width	15(0.314λ_0)	7.5(0.163λ_0)
High	7(0.146λ_0)	7(0.152λ_0)
Size	0.0986 λ_0^2	0.0531 λ_0^2
Bandwidth(VSWR≤2)	73.4%	60.9%
Size reduction	46.1%	

We have also investigated the effects on the impedance bandwidth by varying the height of the folded patch. When the height of folded patch increase (equals to the length of the coaxial probe), the imaginary part of the input impedance increase too. It is also found that the length of the lower patch is mainly used to determine the upper resonance. The length of one arm on the upper patch plays an important role to both the lower and upper resonances. These results are agreed with paper [10].

IV. Conclusion

In this paper, a novel fourth wavelength folded broadband microstrip patch antenna has been demonstrated. The impedance bandwidth, gain and radiation pattern of this antenna are shown. It achieves an impedance bandwidth of 60% and the radiation patterns of our proposed antenna are basically stable over the frequency band. Although the full size of the patch antenna has been reduced more than 45%, the comparable antenna performance is remained.

V. Acknowledgment

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