Compact Wide-band Overlapped Patches Microstrip Antenna

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Abstract — **This paper presents the design, simulation, and measurements of a novel wideband patch antenna. In this paper, the bandwidth of a single layer microstrip patch antenna is enhanced by using multiple resonances without significantly enlarging the size of the proposed antenna. The validity of the design concept is demonstrated by two examples with 51.4% and 56.8% bandwidths.**

Keywords — **Multi-resonance, Patch antenna, Wide band.**

I. INTRODUCTION

MICROSTRIP patch antennas are widely used because of their many advantages, such as the low profile, light weight, and conformity. However, patch antennas have a main disadvantage i.e. a narrow bandwidth. Researchers have made many efforts to overcome this problem and many configurations have been presented to extend the bandwidth. The conventional method to increase the bandwidth is using parasitic patches. In [1], the authors presented a multiple resonator wide-band microstrip antenna. The parasitic patches are located on the same layer with the main patch. In [2], an aperture-coupled microstrip antenna is described with parasitic patches stacked on the top of the main patch. However, these methods typically enlarge the antenna size, either in the antenna plane or in the antenna height. With the rapid development of wireless communications, single-patch wide-band antennas have attracted many researchers' attention [3]–[5]. In [6], the authors presented a wide-band E-shaped patch antenna and demonstrated that its bandwidth could exceed 30%. Wong [7] presents a good survey of available candidate designs that offer a broadband while maintaining the compactness of microstrip antennas. In [8], the impedance bandwidth of a single-layer microstrip patch antenna is enhanced by using multi-resonance technique. This microstrip antenna employs three square patches that are overlapped along their diagonals, this antenna has five distinct resonance frequencies and is designed to operate from 5.09 to 8.61 GHz. It achieves 51.4 percent bandwidth for return loss < -10 dB. It has been noticed that unfortunately the authors failed to give the coordinates and the specifications of the coaxial probe feed, in this paper a trial and error method was used to find out these missing values.

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Another antenna is proposed which is in fact a modification of the overlapped patches microstrip antenna. A slot is incorporated into the complex patch to expand the antenna bandwidth. It achieves 56.8 percent bandwidth for return loss < -10 dB. Simulations will be shown and compared with the measured results.

II. ANTENNAS STRUCTURE, MEASUREMENTS AND SIMULATION RESULTS

A. Overlapped patches microstrip antenna (OPMA)

For a conventional rectangular Microstrip patch antenna of length L and width W, the resonance frequency for any TM_{mn} mode is given by James and Hall [9] to be dependent on the length L, the width W, and the effective dielectric constant of the substrate. But for the dominant TM_{10} mode, the resonance frequency is only dependent on the length L, and the effective dielectric constant. Therefore, it is clear that the resonance frequency of the rectangular microstrip patch antenna is a function of its length (L), so if the microstrip patch antenna has multiple lengths it will be multi-resonance antenna i.e. for every different length there will be a different resonant frequency, hence the bandwidth of the microstrip patch antenna can be enhanced. This technique is utilized in the design of the following microstrip patch antenna.

Three square patches are overlapped along their diagonals to form a non-regular single patch as shown in Fig. 1, The dimensions of the patches are (W_1 X W_1), (W_2 X W_2) and (W_3 X W_3), respectively. S_1 and S_3 indicate the overlapping dimensions of the patches. The structure has five different resonant lengths as follows: L_1, L_2, L_3, L_4 and L_5. As an example, an antenna with the following dimensions was designed: three square patches of dimensions (7.5 X 7.5) mm, (13.5 X 13.5) mm and (7.1 X 7.1) mm with overlapping dimensions S_1=6.4 mm and S_3=4.6 mm, a dielectric substrate of relative permittivity ε_r =2.35 and thickness h =3.175 mm was used [8].

This antenna is fed by a coaxial probe at position (X_f, Y_f) as shown in Fig. 2. The probe feed location and its radius were adjusted in such a way that one can obtain satisfactory performance. Using trial and error, it has been found that at X_f = 4 mm, Y_f = 8 mm, and a probe diameter=1.25mm, the widest bandwidth of this antenna is obtained. The FDTD method full wave simulator *FIDELITY* is used to simulate the overlapped patches microstrip antenna (OPMA) and the obtained results have been compared to other results produced using *IE3D*, a commercial simulator based on the method of moment and good agreements have been found between the two generated results as shown in Fig. 3. For a return loss less than –10 dB the frequency band ranges from 5.09 to 8.61GHz. It achieves 51.4 percent bandwidth for return loss < -10 dB.

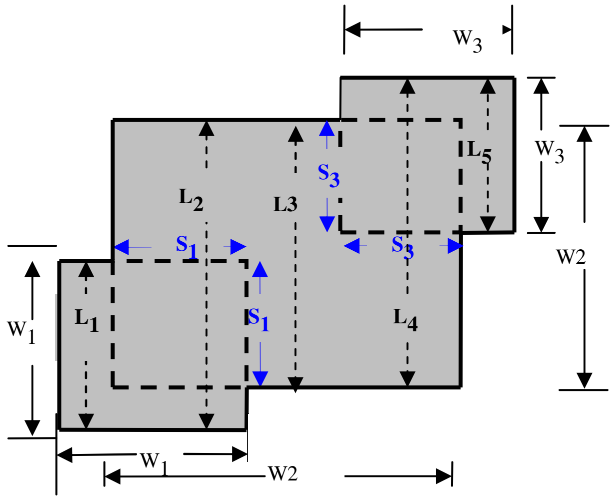

Fig. 1. Geometry of the multi-resonance wideband patch.

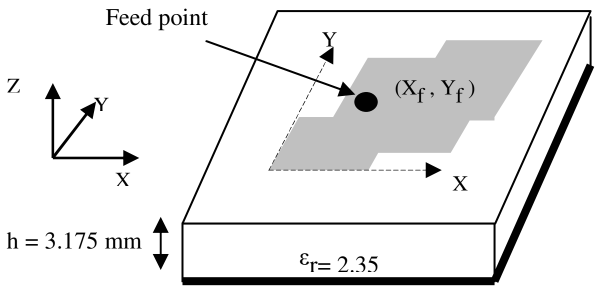

Fig. 2. The OPMA configuration.

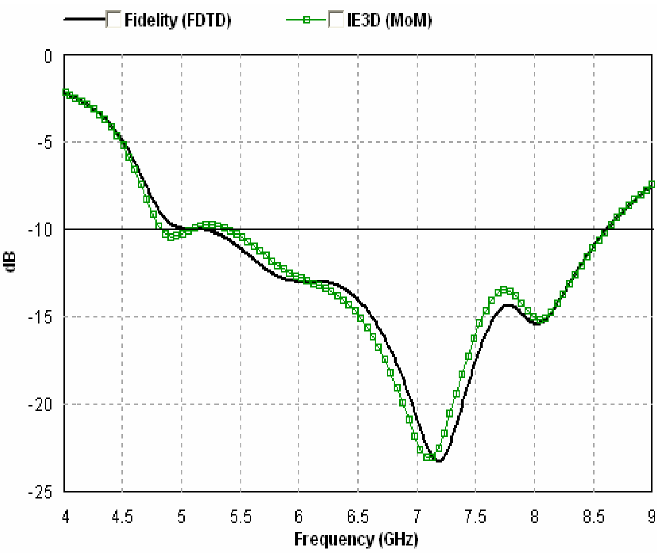

Fig. 3. The return loss of the OPMA.

B. Slotted overlapped patches microstrip antenna (SOPMA)

In the SOPMA, a slot is incorporated into the patch to expand its bandwidth. The OPMA structure described earlier is reused here but modified by inserting a slot. The slot is selected to be 5.1 mm X 0.5 mm and its lower left point is located at (4.625 mm, 5.3 mm). The new SOPMA structure is shown in Fig. 4.

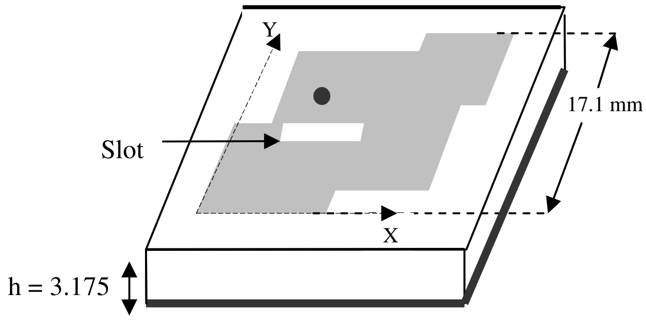

Fig. 4. The SOPMA configuration.

Fig. 5 shows the measured and calculated return loss of the proposed antenna. The SOPMA has 56.8 % bandwidth compared with 51.4 % of the OPMA i.e. wider bandwidth. Also it is clear that the value of S_{11} at resonance is improved by the inserted slot.

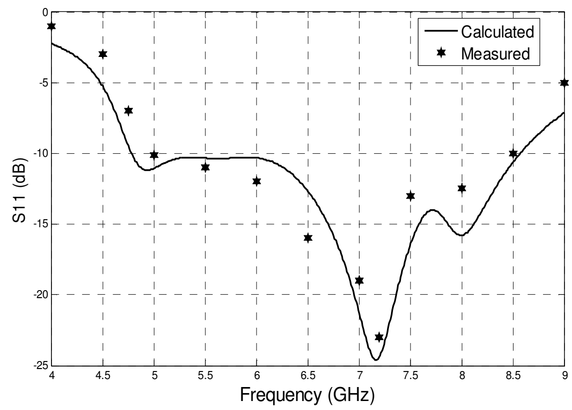

Fig. 5 Measured and calculated return loss of the proposed antenna.

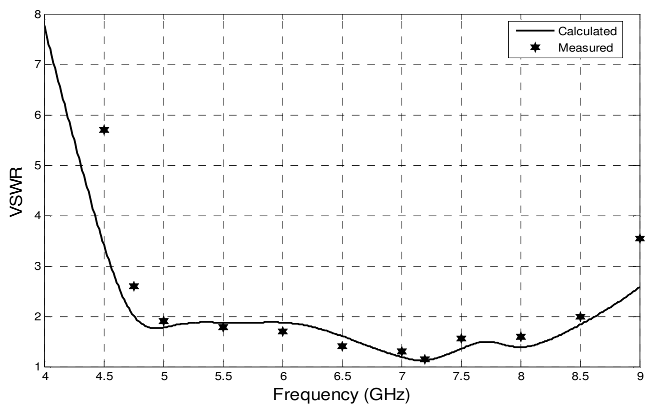

Fig. 6. Measured and calculated VSWR of the proposed antenna

Fig. 6 shows the measured and calculated VSWR of the proposed antenna.The antenna frequency bandwidth with

VSWR<2 covers the fequency range of 4.78-8.57 GHz. This agrees with the less than –10 dB band of the return loss. It has a bandwidth of 56.8 % with the center frequency 6.675 GHz.

The variation of the real part of the input impedance of the SOPMA is shown in Fig. 7. It can be observed that the input resistance is compatible with the 50 ohm characteristics of the input feed line.

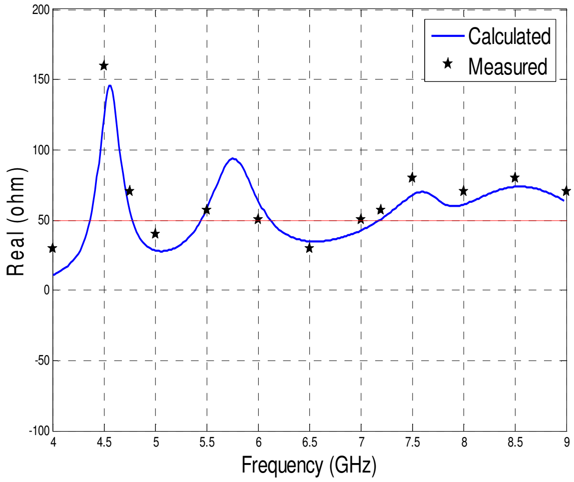

Fig. 7. Measured and calculated real part of the Input Impedance of the proposed antenna

Fig. 8 shows that The SOPMA has five distinct resonance frequencies where the imaginary part of the input impedance equals zero (however no perfect matching is attained). The upper four resonances has VSWR < 2, but the lowest, which is at 4.6 GHz has VSWR close to 3.

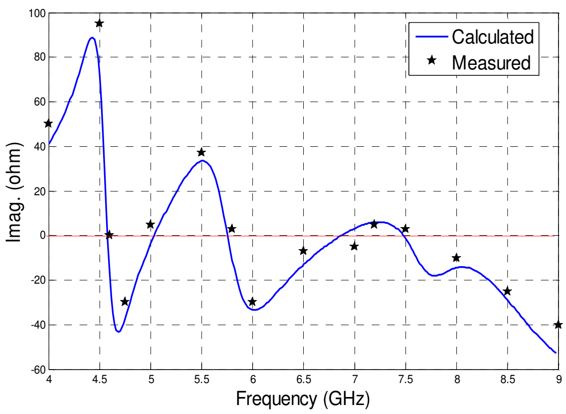

Fig. 8. Measured and calculated imaginary part of the Input Impedance of the proposed antenna.

Since a microstrip patch antenna radiates normal to its patch surface, the elevation pattern for $\phi = 0$ and $\phi = 90$ degrees would be important. Fig. 9 shows the gain Pattern of the OPMA in the XZ-plane ($\phi = 0$ deg.) at different frequencies, it is apparent that this antenna provides stable far field radiation characteristics in the entire operating band with relatively high gain. It is quite clear that the radiation pattern is not symmetrical because of the asymmetry of the patch. It is noticed that at 6.21 GHz the maximum gain is obtained in the broadside direction and this is measured to be 5.63 dBi for both, $\phi = 0$ and $\phi = 90$ degrees. The back-lobe radiation is sufficiently small and is measured to be -14 dBi for the above plot. This low back-lobe radiation is an added advantage for using this antenna in a cellular phone, since it reduces the amount of electromagnetic radiation, which travels towards the users head.

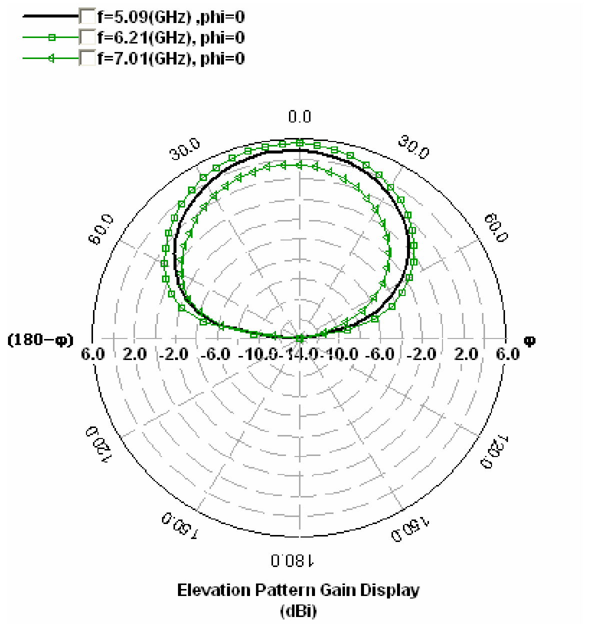

Fig. 9. Radiation Pattern of the SOPMA in the XZ-plane.

Fig. 10 shows the radiation pattern of the SOPMA in the YZ-plane ($\phi = 90$ deg.) at different frequencies, it is Clear that this pattern is also not symmetrical due to the same cause. However, the beamwidth in both planes is wide enough.

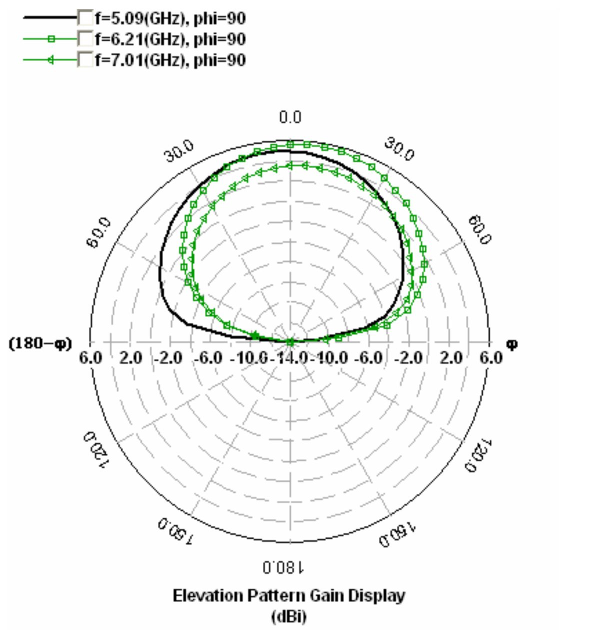

Fig. 10. Radiation Pattern of the SOPMA in the YZ-plane.

Fig. 11 shows that the resonant frequencies of the SOPMA are lower than the resonance frequencies of the OPMA. This is of course, the effect of the slot which adds an inductance to the equivalent circuit of the patch, this added inductance naturally lowers the resonance frequencies as indicated in Fig. 11.

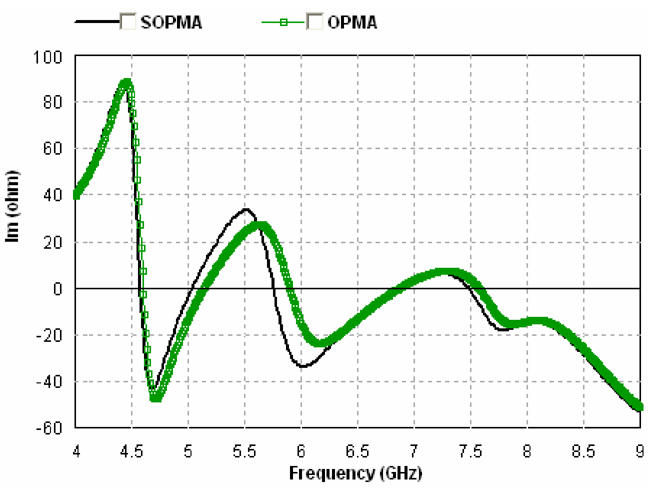

Fig. 11. The imaginary part of the input impedance of both the OPMA and the SOPMA

Fig. 12 illustrates the gain of the OPMA against frequency, the gain is greater than 2 dBi in a frequency range (4.31-7.88 GHz), and the gain variations are less than about 4 dBi across the operating frequency. Due to the fact that the radiating apertures of the two edge patches are relatively smaller compared to those of the main patch, the gain decreases at higher frequencies.

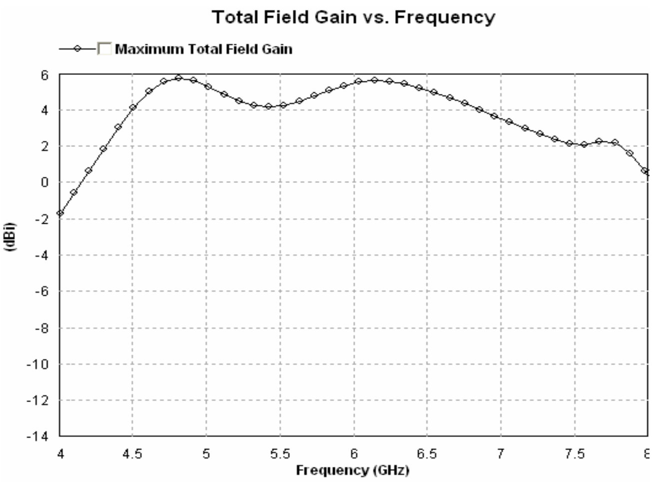

Fig. 12. Gain of the SOPMA

III. Conclusion

In this paper, two designs for small-size wide-bandwidth microstrip patch antennas have been presented. The first design employs three square patches that are overlapped along their diagonals and has been simulated using two commercial field solvers, the obtained bandwidth was 51.4%. In the second design which has been fabricated, a slot is incorporated into the complex patch to expand its bandwidth, it achieves 56.8 percent bandwidth for return loss < –10 dB. Simulations have been shown and compared with the measured results and good agreements have been found. Each structure of these designs can be easily fabricated on a single-layer and relatively thin substrate for applications in hand-held devices. It has been shown that these antennas can easily be used in other frequency bands with different substrate materials.

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