Studies on a Rectangular Shaped Compact Broadband Microstrip Patch Antenna

Kalyan Mondal and Partha P. Sarkar

Abstract — **A rectangular small size and wideband microstrip patch antenna is presented. Performance is improved introducing slits in the ground plane. Proposed antenna exhibits enhanced bandwidth with multi resonant frequencies. Simulated results obtained by Ansoft designer software are compared with the measured data. A parametric study is also presented.**

Keywords – **Rectangular patch, Broadband, Mobile communication, Ansoft designer.**

I. Introduction

Microstrip patch antennas are very popular for mobile communications in public and military applications due to their intrinsic characteristics like easy design, low cost, light weight, availability of material etc. It is very important for microstrip antenna to measure the bandwidth, radiation pattern, gain and reflection coefficient for specific values of length and width at different resonating frequencies [1]. The conventional form of the microstrip patch antenna is metallic radiating patch and metallic ground plane with dielectric substrate. In between two metal planes a dielectric substrate is inserted. The antenna has an impedance bandwidth of 1-2% in general. To improve the bandwidth a parasitic patch is used, either in another layer (stacked geometry) or in the same layer (coplanar geometry). However, the stacked geometry has the disadvantage of increasing the thickness of the antenna while the coplanar geometry has the disadvantage of increasing the lateral area of the antenna [2-3]. The extensive research is carried out to improve the impedance bandwidth of microstrip patch antennas. There are several ways to improve the bandwidth of an antenna. It has been proved that the bandwidth of the antenna can be increased by reducing the ground plane size and through the use of various feeding methods or stacked patches [4-6]. A wideband rectangular slot antenna for unidirectional radiation patterns is investigated in which a U-shaped tuning stub is used to improve the matching. There suitable slits at the radiating edges are used to improve the return loss and bandwidth [6-9]. In this paper, compactness and large bandwidth is obtained by cutting one slot in the patch and three slots in the ground plane. The proposed antenna is successfully designed and the simulated results are in good agreement with the measured results.

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II. Antenna Design

The conventional rectangular microstrip patch antenna is shown in Fig. 1 whereas modified rectangular patch, modified ground plane and proposed microstrip patch antenna are shown in Fig. 2, Fig. 3(a) and Fig. 3(b) respectively. Fig. 3(c) shows the original photograph of proposed microstrip patch antenna. The proposed antenna is designed using PTFE substrate with relative permittivity 2.4, thickness 1.6 mm and loss tangent 0.0016. The diameter of the feeding hole is 1mm and it is located at 1 mm from the right edge and 1.5 mm from the bottom edge of radiating patch as shown in Fig. 3(b). To improve the bandwidth and compactness a slot is incorporated in the microstrip patch and other three slots are incorporated in the ground plane. About 50% of the ground plane has been removed. So still it can be operate as a microstrip antenna. All the dimensions of patch, ground plane, and slots are listed in Table I and Table II.

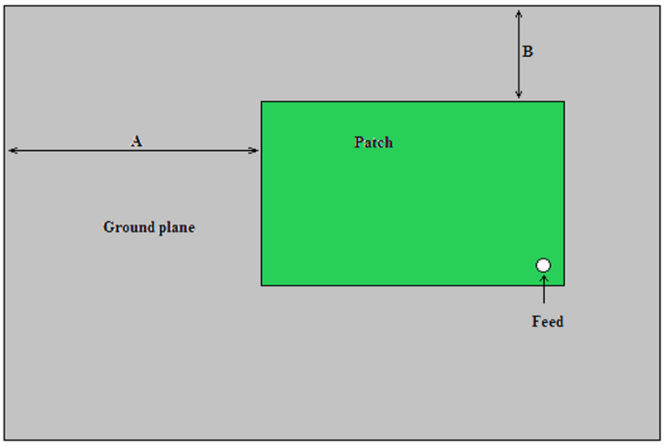

Fig. 1.Conventional rectangular patch antenna

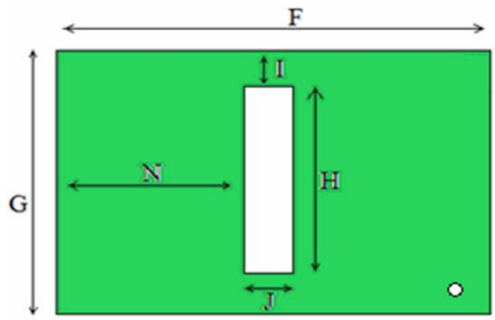

Fig. 2. Modified top view of microstrip patch antenna

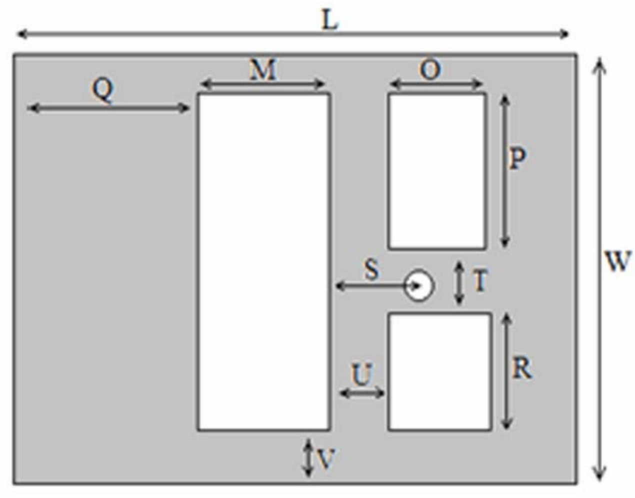

Fig. 3 (a). Modified ground plane of the proposed antenna

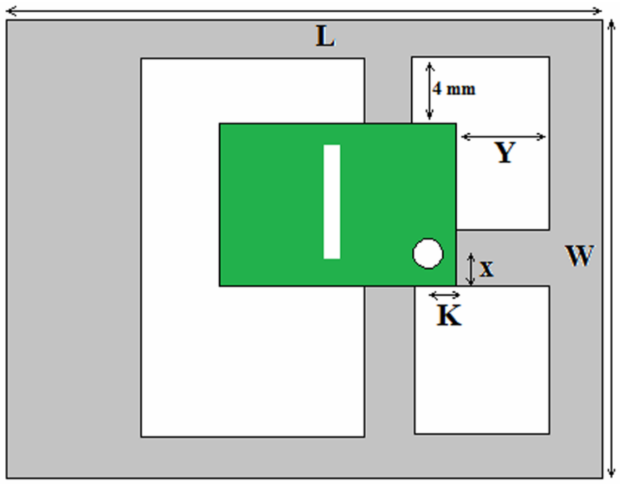

Fig. 3(b). Proposed microstrip patch antenna

Fig. 3(c). Photograph of the proposed antenna

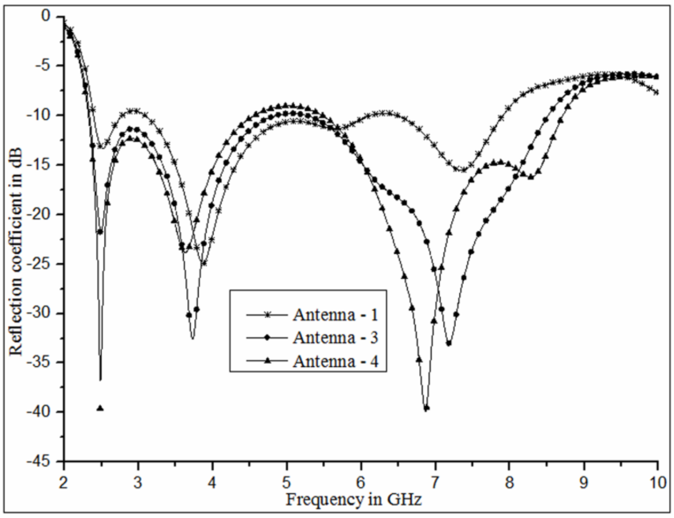

Fig. 4. Reflection Coefficient versus frequency of Antenna-1 (M = 18 mm), Antenna-3 (M = 15 mm) and Antenna-4 (M = 14 mm)

TABLE I
GEOMETRICAL PARAMETERS AND DIMENSIONS OF FIG. 1, FIG. 2, FIGS. 3(a) AND 3(b)

Parameters (mm)	Antenna-1	Antenna-2 (Proposed)	Antenna-3	Antenna-4	Antenna-5	Antenna - 6	Antenna-7
F	14.5	14.5	14.5	14.5	14.5	14.5	14.5
G	9.5	9.5	9.5	9.5	9.5	9.5	9.5
H	7.0	7.0	7.0	7.0	7.0	7.0	7.0
I	1.29	1.29	1.29	1.29	1.29	1.29	1.29
J	1.0	1.0	1.0	1.0	1.0	1.0	1.0
K	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L	34.0	34.0	34.0	34.0	34.0	34.0	34.0
M	18.0	16.0	15.0	14	16	16	16
N	7.92	7.92	7.92	7.92	8.92	9.92	10.92
O	7.0	7.0	7.0	7.0	7.0	7.0	7.0
P	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Q	6	8	9	10	8	8	8
R	7.5	7.5	7.5	7.5	7.5	7.5	7.5
S	2.0	2.0	2.0	2.0	2.0	2.0	2.0
T	3.0	3.0	3.0	3.0	3.0	3.0	3.0
U	1.0	1.0	1.0	1.0	1.0	1.0	1.0
V	2.0	2.0	2.0	2.0	2.0	2.0	2.0
W	25	25	25	25	25	25	25
X	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Y	5.0	5.0	5.0	5.0	5.0	5.0	5.0
A	12.5	12.5	12.5	12.5	12.5	12.5	12.5
B	6.0	6.0	6.0	6.0	6.0	6.0	6.0

TABLE II
GEOMETRICAL PARAMETERS AND DIMENSIONS OF FIG. 1, FIG. 2, FIGS. 3(a) AND FIG. 3(b)

Param eters (mm)	Anten na-8	Anten na-9	Anten na-10	Anten na-11	Anten na -12	Anten na-13	Anten na-14	Anten na -15
F	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
G	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
H	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
I	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29
J	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
K	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L	38	42	46	50	34	34	34	34
M	16	16	16	16	16	16	16	16
N	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92
O	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
P	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Q	8	8	8	8	8	8	8	8
R	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
S	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
T	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
U	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
V	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
W	25	25	25	25	29	33	37	41
X	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Y	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
A	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
B	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0

TABLE III
SIMULATED RESULTS OF THE ANTENNAS FOR PARAMETERS VARIATIONS

Antennas	Resonance frequency (in GHz)	% of Bandwidth	Return Loss (Max) (in dB)
Antenna - 1	2.52, 3.86 and 7.34	14% and 87%	-25
Antenna - 2 (Proposed)	2.46, 3.78 and 7.3	112%	-40
Antenna - 3	2.5, 3.72 and7.18	69% and 47%	-33
Antenna - 4	2.48, 3.62 and 6.86	64% and 45%	-40
Antenna - 5	2.5, 3.8 and 7.44	110%	-37
Antenna - 6	2.5, 3.78 and 7.46	110%	-41
Antenna - 7	2.5, 3.76 and 7.4	110%	-28
Antenna - 8	3.7 and 7.24	38% and 41%	-48
Antenna - 9	3.62 and 7.0	29% and 38%	-44
Antenna - 10	6.84	22% and 37%	-52
Antenna - 11	6.72	15% and 39%	-49
Antenna - 12	3.38 and 7.50	50% and 43%	-28
Antenna - 13	3.36 and 7.51	36% and 40%	-21
Antenna - 14	7.48	23% and 37%	-18
Antenna - 15	7.44	8% and 35%	-19

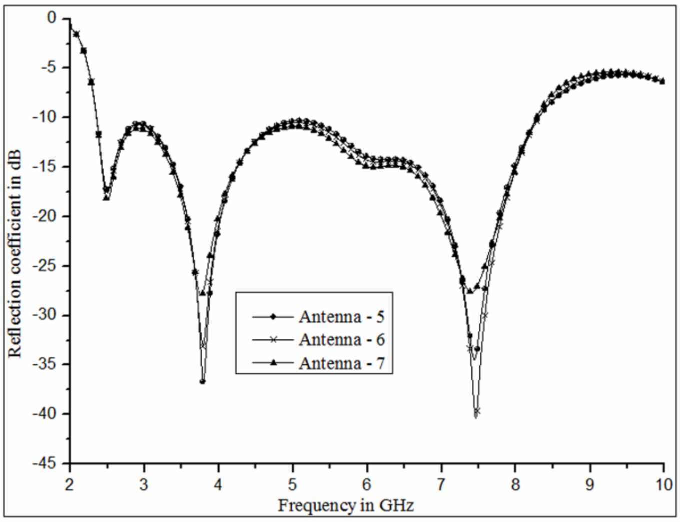

Fig. 5. Reflection Coefficient versus frequency for various position of slot line on the radiating patch (for N = 8.92 mm, N = 9.92 mm and N = 10.92 mm)

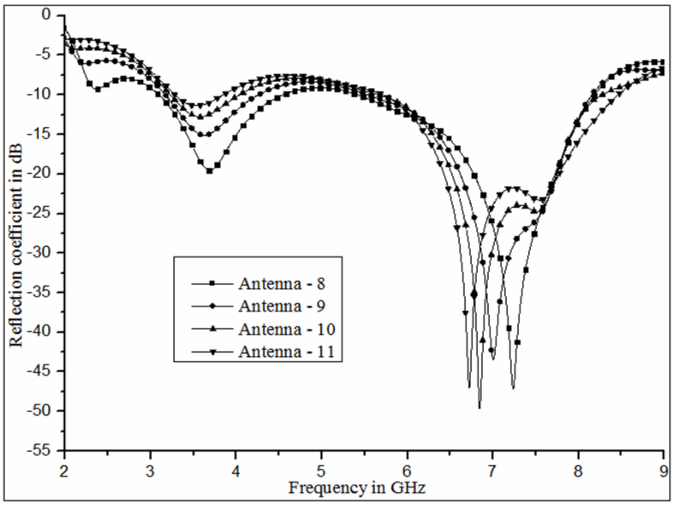

Fig. 6. Reflection Coefficient of Antenna-8 (L = 38 mm), Antenna- 9 (L = 42 mm), Antenna-10 (L = 46 mm) and Antenna-11 (L = 50 mm)

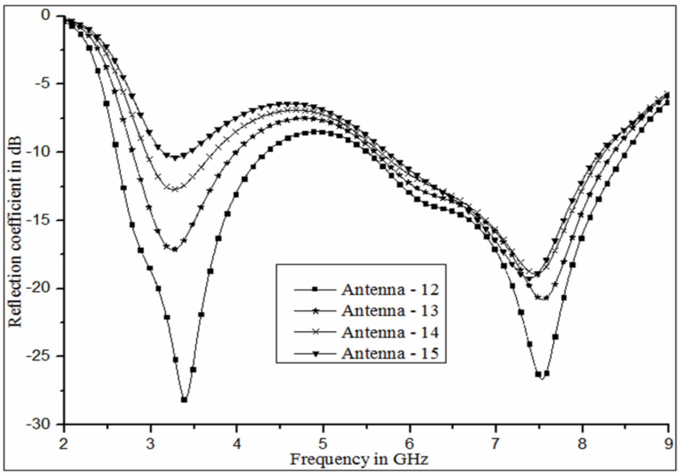

Fig. 7. Reflection Coefficient versus frequency of Antenna-12 (W = 29 mm), Antenna-13 (W = 33 mm), Antenna-14 (W = 37 mm) and Antenna-15 (W = 41 mm)

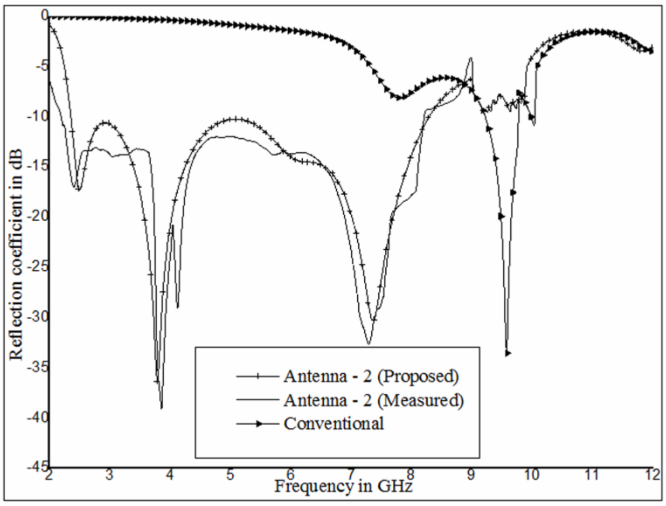

Fig. 8. Simulated and measured results of the proposed and conventional antenna

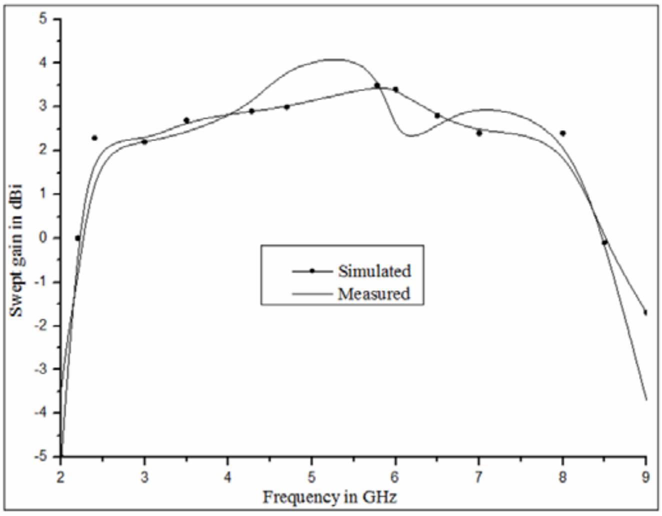

Fig. 9. Simulated and measured gain of the proposed antenna at ($\theta = 0^0$ and $\varphi = 0^0$)

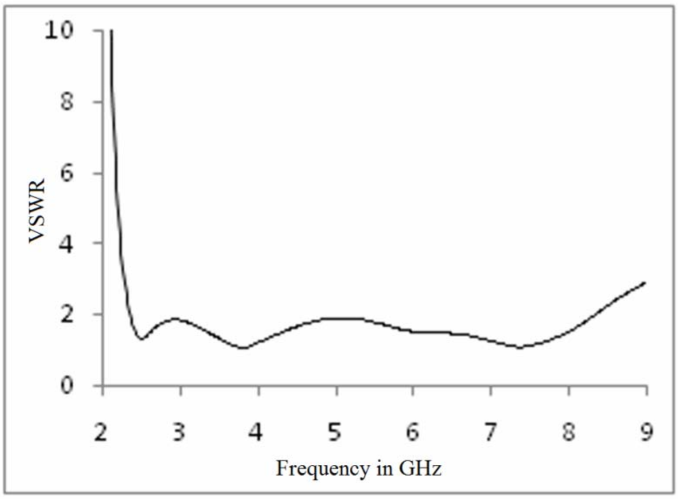

Fig. 10. VSWR versus frequency plot of the proposed antenna

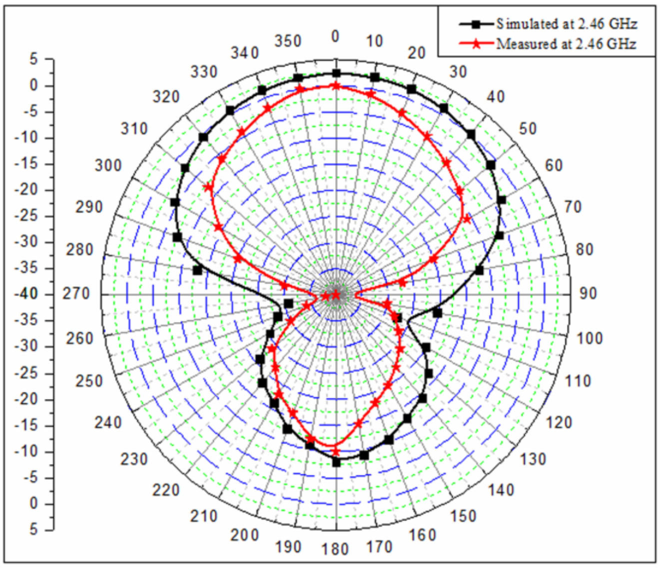

Fig. 11(a)

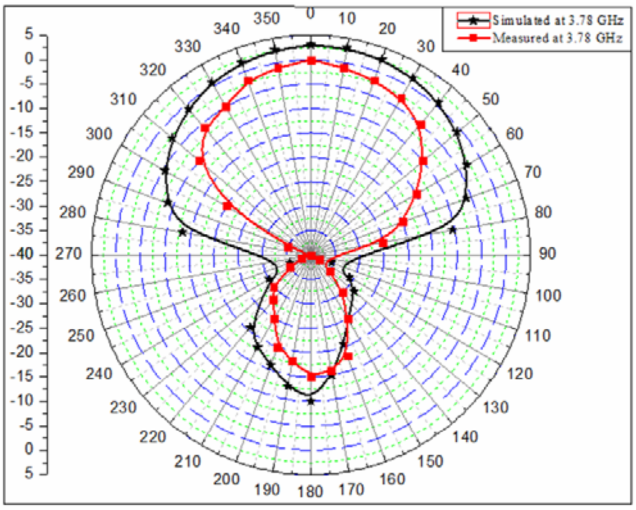

Fig. 11(b)

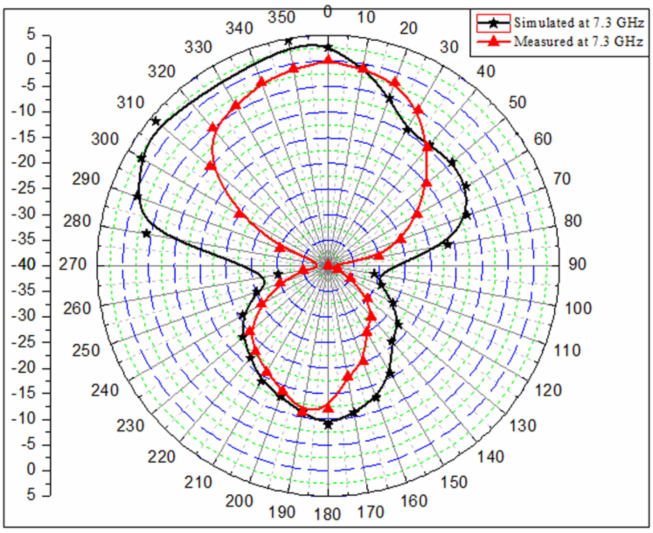

Fig. 11(c)

Fig. 11. H-plane Radiation Pattern of the proposed antenna at (a) 2.46 GHz, (b) 3.78 GHz and (c) 7.3 GHz

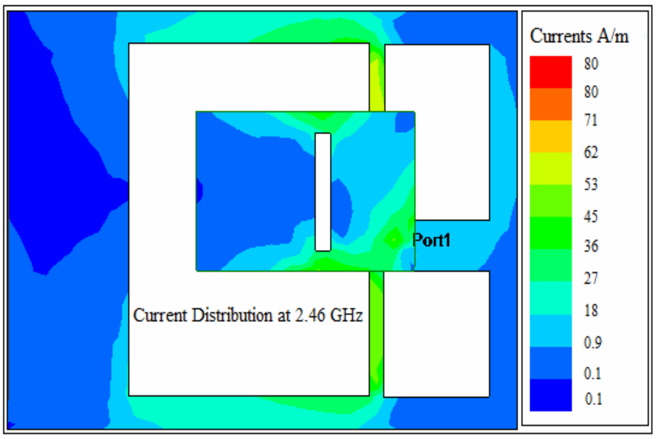

Fig. 12 (a)

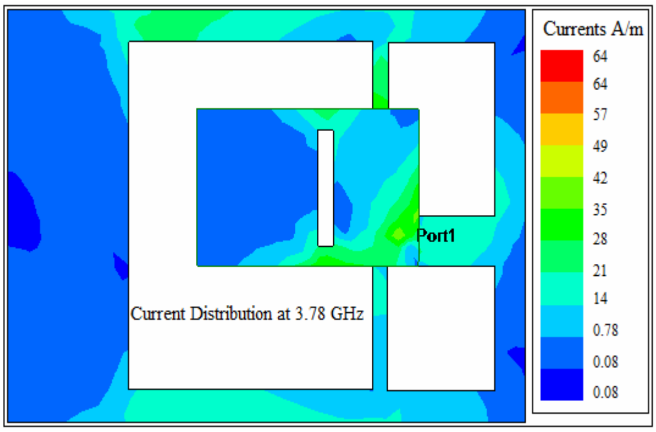

Fig. 12(b)

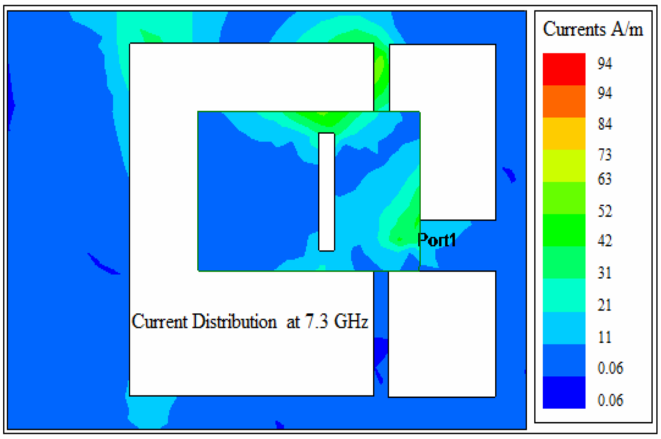

Fig. 12(c)

Fig. 12. Surface current distribution of the proposed antenna at (a) 2.56 GHz, (b) 3.78 GHz and (c) 7.3 GHz

Fig. 13 Experimental setup of the proposed antenna

III. Results And Discussion

Fig. 4 indicates that if the length of the slot (*M*) on the ground plane is decreased from 18 mm to 14 mm keeping other optimum dimension of antenna -2 parameters constant then the value of reflection coefficient is decreased significantly from -25dB to -40dB with maximum percentage bandwidth of 87% (2.39 GHz-6.1 GHz) to 64% (2.33 GHz-4.54 GHz). From Fig. 5 it is found that the percentage bandwidth of antenna-5, antenna-6 and antenna-7 remain almost constant (110%) with variation of parameter *N*, from 8.92 mm to 10.92 mm. From Fig. 6 it is observed that if length of the parameter *L* is gradually increased from 38 mm to 50 mm and all other designed parameters remain constant at optimum value mentioned for antenna -2, then the resonating frequency position changes with maximum percentage bandwidth from 41% (5.4 GHz-8.2 GHz) to 39% (5.7 GHz-8.46 GHz). Fig. 7 indicates that if the length of the parameter *W* on the ground plane is increased slowly from 29 mm to 41 mm keeping other parameters constant at optimum value of antenna-2, the value of reflection coefficient is increased marginally from -28dB to -19dB with maximum percentage bandwidth of 50% (2.6 GHz-4.35 GHz) to 35% (5.7 GHz-8.2 GHz). But the resonant frequency is not changed significantly. However after several simulations, optimized dimensions are chosen and followings these dimensions finally proposed antenna (Antenna - 2) has been designed. The reflection coefficient, compactness and bandwidth are improved due incorporation of multiple number of rectangular slots in the ground plane as well as in the radiating patch. Simulated and measured results of reflection coefficient of conventional and modified antenna-2 are presented in Fig. 8. The proposed antenna offers simulated percentage bandwidth of 112% (2.34 GHz - 8.3 GHz), minimum reflection coefficient -40dB and resonating frequencies at 2.46 GHz, 3.78 GHz and 7.3 GHz. The measured percentage bandwidth of 115% (2.2 GHz – 8.22 GHz) with 74% compactness is achieved. The resonance frequency of the conventional rectangular antenna is indicated at 9.58 GHz and it is reduced at 2.5 GHz by introducing slots on the radiating patch and ground plane. Fig. 9 shows the simulated and measured gain of the proposed antenna**.** The measured peak antenna gains according to the operating frequency at 2.46, 3.78 and 7.3 GHz are 1.5, 2.2 and 3 dBi respectively. The maximum swept gain is obtained with angle $\theta = 0^0$ and $\varphi = 0^0$ over the frequency range 2 GHz to 10 GHz. Here θ and φ are the elevation and azimuth angle of the antenna. To enhance the bandwidth and compactness of the proposed antenna a little bit antenna gain has been sacrificed. The proposed antenna offers stable VSWR between the ranges 1 to 2 (shown in Fig. 10). The simulated and measured H-plane radiation patterns of the fabricated antenna-2 at 2.46, 3.78 and 7.3 GHz are plotted and compared in Figs. 11(a) to 11(c). The maximum power is radiated from the radiating patch of the antenna. According to the Fig. 11(a) back radiation is 15dB down than front radiation. So, back radiation is around 5% of front radiation. The surface current distributions according to the operating frequency of the proposed antenna are presented in Fig. 12(a) to 12(c).The maximum surface current density varies from about 64 A/m (at 3.78 GHz) to 94 A/m (at 7.3 GHz) and reflection coefficient is varied from about -18dB to -52 dB. From current distribution new researchers may get the concept of radiation from different points of the antenna. The dimension and simulated results of all the antennas for variations of parameters are listed in Table I, Table II, and Table III respectively. For measurements of gain, and radiation pattern of the fabricated antenna standard microwave test bench of our laboratory has been used and it has been shown in Fig. 13.

IV. CONCLUSION

A good number of research works have been performed on microstrip antennas. Researchers have been trying to enhance bandwidth, gain and to reduce its size. Generally one or two achievements simultaneously are obtained by a single antenna. Here in this paper size reduction and broad-banding have been achieved by the single antenna. Novelty of the paper is that the same antenna provides good bandwidth and compactness simultaneously.

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