Broadband Shorted Plate Proximity Fed Rectangular Microstrip Antenna

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ABSTRACT

The compact microstrip antenna is realized by placing the shorting plate or shorting post along the zero field line at the fundamental mode of conventional half wavelength microstrip antenna. The shorted plate microstrip antenna has higher bandwidth as compared to the conventional microstrip patch. The bandwidth of microstrip antenna is increased by using proximity feeding technique. In this paper the broadband proximity fed configurations of shorted plate rectangular microstrip antennas are discussed. They give bandwidth of more than 350 MHz. Further a pair of rectangular slots cut broadband shorted plate proximity fed rectangular microstrip antenna is proposed. The proposed configuration gives a bandwidth of nearly 480 MHz with a gain of more than 5 dBi over the VSWR bandwidth. Since the shorted patch is used, the antenna shows maximum in the radiation pattern in the end-fire direction.

Keywords

Rectangular microstrip antenna, Broad band microstrip antenna, shorted plate microstrip antenna, pair of rectangular slots

1. INTRODUCTION

The conventional microstrip antenna (MSA) is typically a half wavelength resonator [1 – 3]. Using this conventional patch the compact MSA is realized by placing the shorting post or the shorting plate along the zero field line of the patch at its fundamental mode. The compact rectangular MSA (RMSA) is realized by placing the shorting plate along the zero field line for the fundamental TM_{10} mode [1]. The shorting plate loaded RMSAs have larger BW with reduced gain as compared to the conventional RMSA. The broadband RMSA is realized by fabricating the RMSA on thicker substrate having lower dielectric constant [1 – 3]. The quality factor of the cavity below the patch is reduced for thicker substrate (h), which yields larger bandwidth (BW). However for h $\geq 0.04\lambda_0$, the BW is limited by the feed probe inductance. By using the simpler proximity feeding technique the antenna BW is increased for substrate thickness greater than $0.07\lambda_0$ [4]. In the proximity fed MSA, the coupling
strip is either placed below the patch or placed inside the slot which is cut in the patch or it is kept in the same plane of the patch. The maximum bandwidth (BW) is realized when the coupling strip is placed below the patch [5]. The broadband MSA is also realized by using the multi-resonator gap-coupled or stacked configurations [6, 7]. The multi-resonator configurations increase the antenna size either in horizontal or vertical directions. By cutting a slot of different shapes like, U-shape, V-shape and rectangular shape, inside the MSA, a broader BW has been realized [8 – 10]. These slotted MSAs are optimized using thicker substrates of 0.06 to $0.07\lambda_0$. However for h > $0.08\lambda_0$, their BW is limited by the feed probe inductance. Using the proximity feeding, the BW of these slotted antennas is increased for substrate thickness of more than $0.08\lambda_0$ [11].

In this paper, a shorted plate RMSA is discussed. Further the BW of shorted plate RMSA is increased by using the proximity feeding technique. In first configuration the shorted plate was placed below the patch. This configuration gives a BW of more than 420 MHz at center frequency of around 900 MHz. In the second configuration the coupling rectangular strip is placed inside the slot which is cut in the patch. Due to the reduced coupling between the patch and strip, this configuration realizes a BW of more than 220 MHz. In the third configuration the coupling rectangular strip is placed in the same plane of the shorted plate RMSA and it is placed very close to the patch edge. This configuration realizes a BW of more than 380 MHz. In all these configurations a gain of more than 4 dBi over the operating BW with peak gain very close to 5 dBi is observed. Due to the use of shorted plate, the radiation pattern in the proximity fed MSAs is maximum in the end-fire direction. Further a pair of rectangular slot cut shorted plate RMSA is proposed. It gives a BW of nearly 480 MHz at the center frequency of around 900 MHz. All these configurations were first optimized using IE3D software followed by experimental verifications [12]. These antennas were optimized using the air substrate to realize maximum radiation efficiency. The IE3D simulations were carried out using an infinite ground plane. Hence to realize the effect of infinite ground plane, a larger square ground plane having dimension of 70 x 70 cm^2 is used in the measurements. The antenna is fed using the N-type connector having probe diameter of 0.32 cm. The radiation pattern was measured by keeping the minimum far field distance between the reference antenna and the antenna under test in the minimum reflection surroundings [13]. The antenna gain is measured using the three antenna method [13].

2. SHORTED PLATE RMSA

The RMSA with a voltage distribution for TM_{10} mode is shown in Figure 1(a). The field is minimum in the center of the patch and the compact quarter wavelength shorted plate RMSA is obtained by placing the shorting post or the shorting plate along the zero field line as shown in Figure 1(b). For the substrate thickness of 1.0 cm and at the resonance frequency of around

900 MHz, the RMSA and the shorted plate RMSA BW's are 56 MHz and 125 MHz, respectively. The radiation pattern for RMSA is in the broadside direction. The pattern for shorted plate RMSA shows maximum radiation in end-fire direction. The cross-polarization levels are higher due to the un-symmetrical voltage distribution around the patch. The shorted plate RMSA has lower gain due to the reduced aperture area.

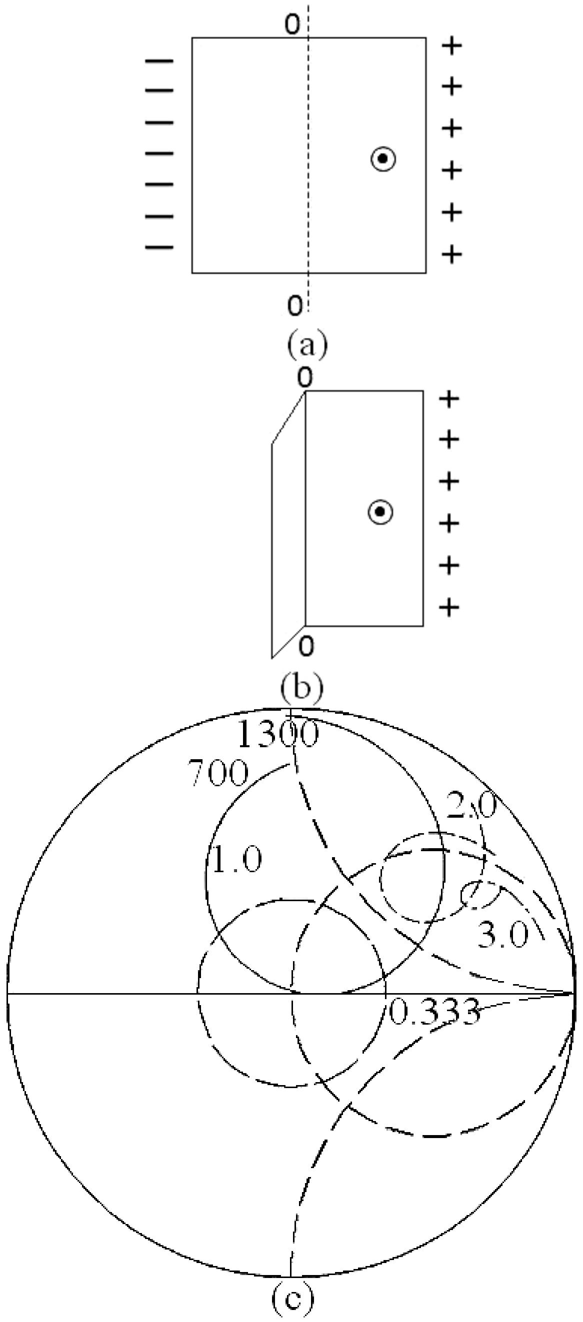

Fig 1: (a) RMSA, (b) shorted plate RMSA and (c) input impedance plots for varying substrate thickness for shorted plate RMSA

The input impedance plots for shorted plate RMSA for substrate thickness of 1.0, 2.0 and 3.0 cm is shown in Figure 1(c). With the increase in the thickness the input impedance locus becomes inductive due to the probe inductance and the antenna response can not be optimized for broader BW inside the VSWR = 2 circle. Therefore to realize the impedance matching and to increase the BW, proximity feeding technique is used by using the thicker substrates.

3. PROXIMITY FED SHORTED PLATE RMSA

The proximity fed shorted plate RMSA is shown in Figure 2(a, b). The coupling rectangular strip is placed below the patch. The antenna response is optimized by using the parametric study by varying the strip dimensions and its position and the substrate thickness for the strip and the shorted plate RMSA. The input impedance plots for these variations are shown in Figure 3(a – c).

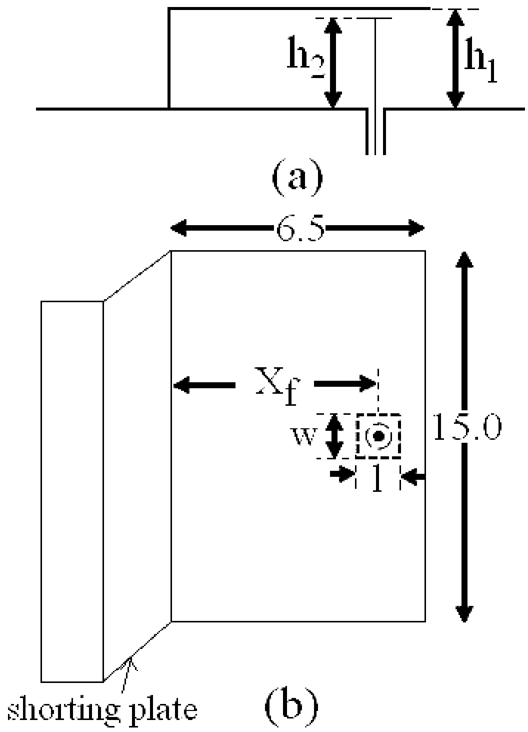

Fig 2: (a) Top and (b) side views of proximity fed shorted plate RMSA

The input impedance locus is capacitive for smaller h_1 as shown in Figure 3(a) and therefore in those cases a broader BW cannot be realized. The similar effects were observed for variations in h_2. With an increase in strip length (l) the loop size increases which increases the BW, as shown in Figure 3(b). But for larger l, the loop does not lie completely inside the VSWR = 2 circle, which reduces the BW. Also the loop rotates in the clockwise direction in the smith chart, due to the decreased capacitive impedance. The similar behavior is observed for variations in w. The variations in X_f changes the coupling between the shorted patch mode and the coupling strip which further changes the loop size as shown in Figure 3(c). Thus the strip dimensions, its position below the patch were optimized so that the loop size lies completely inside the VSWR = 2 circle. The optimized broadband response is shown in Figure 4.

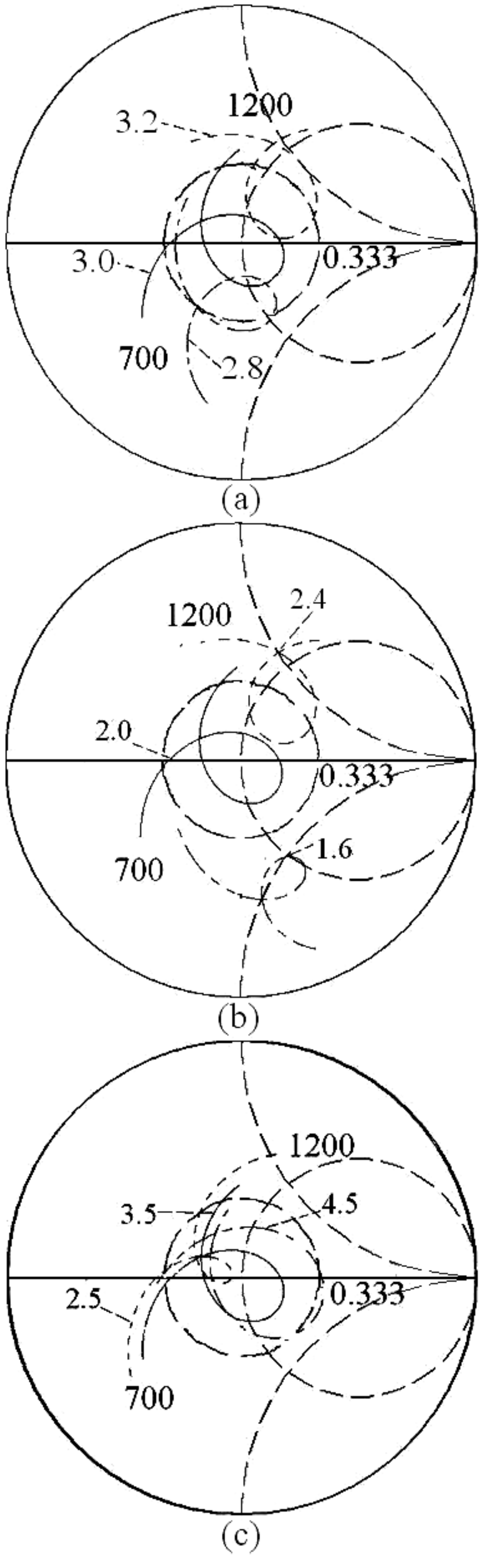

Fig 3: Input impedance plots for variations in (a) h_1, (b) l, (c) X_f for proximity fed shorted plate

The simulated BW is 422 MHz (47%). The antenna was fabricated using the copper strip and the measurement was carried out. The measured BW is 418 MHz (46.7%) as shown in Figure 4.

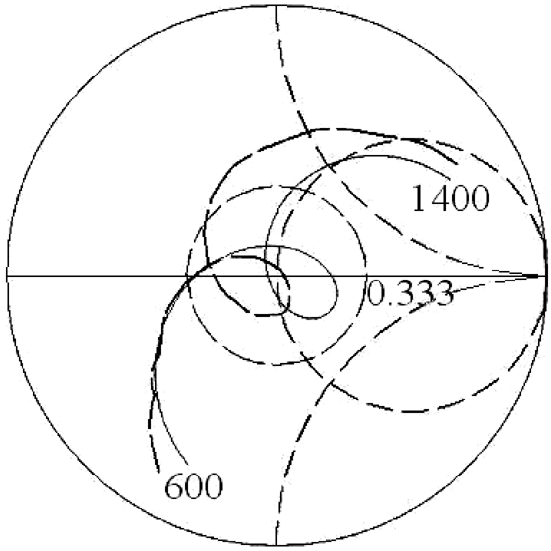

Fig 4: Input impedance plot for proximity fed shorted plate RMSA, (——) simulated, (— —) measured

In another proximity fed configuration, the coupling strip is placed inside the slot which is cut in the shorted plate RMSA as shown in Figure 5. In the parametric study this configuration shows similar behavior for different parameters as shown by the above configuration. The simulated BW is 232 MHz (25.7%) whereas the measured BW is 224 MHz (24.8%). Similar to the above configuration, the radiation pattern shows maximum radiation in the end-fire direction with broadside level 3 dB down.

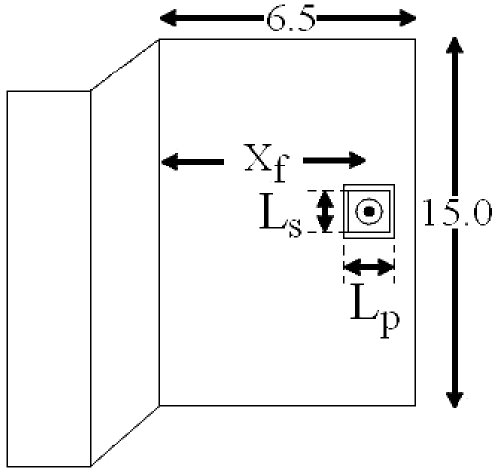

Fig 5: Proximity fed shorted plate RMSA with coupling strip inside the patch

In the next proximity fed configuration the coupling strip is placed close to the edge of the shorted patch as shown in Figure 6(a, b). This configuration shows similar behavior for variations in strip dimensions, substrate thickness and the gap between the RMSA and strip to that shown by configuration in Figure 2(a, b). By optimizing the above parameters, a broadband response as shown in Figure 6(c) is obtained. The simulated BW is 390 MHz (43.3%) whereas the measured BW is 382 MHz (42.2%). Similar to the above proximity fed configuration the radiation pattern is maximum in the end-fire direction.

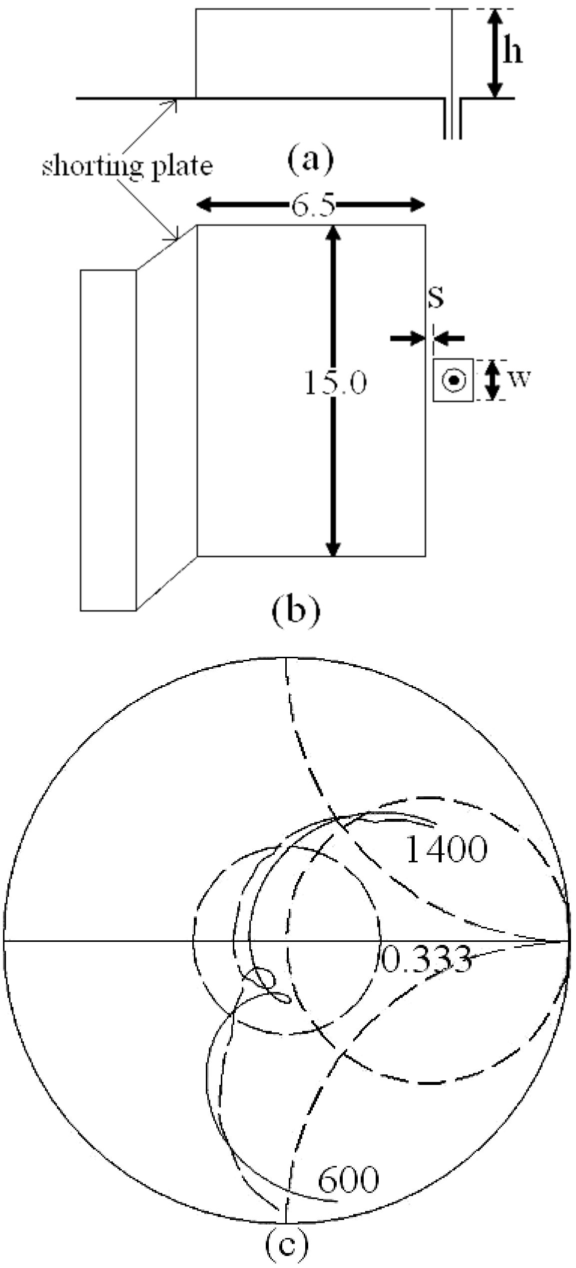

Fig 6: (a) Top and (b) side views of side proximity fed shorted plate MSA and its (c) input impedance plots, (——) simulated, (— —) measured

4. PAIR OF SLOTS CUT PROXIMITY FED SHORTED PLATE MSA

The BW of proximity fed shorted plate MSA is further increased by cutting the pair of rectangular slots inside the patch as shown in Figure 7. Since out of the three proximity fed configurations discussed above, when the coupling strip is placed below the shorted patch, yields larger BW. Therefore in the slot cut shorted plate MSA, the coupling strip is placed below the patch. To realize the symmetrical configuration pair of slots were cut with respect to the proximity feed. For broader BW, the slot dimensions, separation between the pair of slots and the proximity feed point location were optimized. The simulated input impedance and VSWR plots are shown in Figure 8.

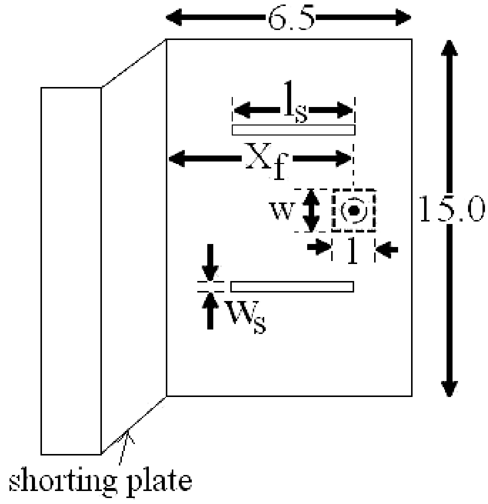

Fig 7: Proximity fed pair of rectangular slot cut shorted plate MSA

The simulated BW is 484 MHz (53.7%). The antenna is fabricated using the copper strip and it was suspended in air using the foam substrate placed towards the antenna corners. The antenna is fed using the N-type connector and the measurement was carried out using the ground plane of size 70 x 70 cm^2. The measured BW is 490 MHz (54.4%). The measured result is in close agreement with the simulated result. The photograph of the fabricated prototype is shown in Figure 9. The radiation pattern for the pair of rectangular slot cut shorted MSA is measured. The pattern at the center frequency of the BW is shown in Figure 10(a). Due to the shorted patch, the radiation pattern is maximum in the end-fire direction with higher cross-polarization levels. The gain variation over the BW is shown in Figure 10(b). The gain is more than 5 dBi over the entire BW with peak gain very close to 6.5 dBi. The results for all the configurations are summarized in Table 1.

5. CONCLUSIONS

The compact variation of conventional RMSA, a shorted plate RMSA is discussed. It has larger BW as compared to the RMSA. Using the thicker substrate the BW of shorted plate RMSA is increased by using proximity feeding technique. Three configurations of proximity fed shorted plate MSAs are discussed. A larger BW is realized when the strip is placed below the patch or very close to patch edge and in the same plane. Further a pair of rectangular slots cut proximity fed shorted plate MSA is proposed. It gives a BW of 480 MHz centered at around 900 MHz. Since the shorted patch is used, the radiation pattern is maximum in the end-fire direction with a higher cross polarization levels. The antenna has gain of more than 5 dBi over the operating BW. Although the cross polarization level higher, they will be of an advantage in the mobile communication environment wherein the antennas with lower cross polar levels will lead to a larger signal loss.

Table 1: Comparison between different proximity fed shorted plate MSAs

Configuration shown in	Simulated BW MHz, %	Measured BW MHz, %
Figure 2 (a, b)	422, 47	418, 46.7
Figure 5	232, 25.7	232, 25.7
Figure 6 (a, b)	390, 43.3	382, 42.2
Figure 7	484, 53.7	490, 54.4

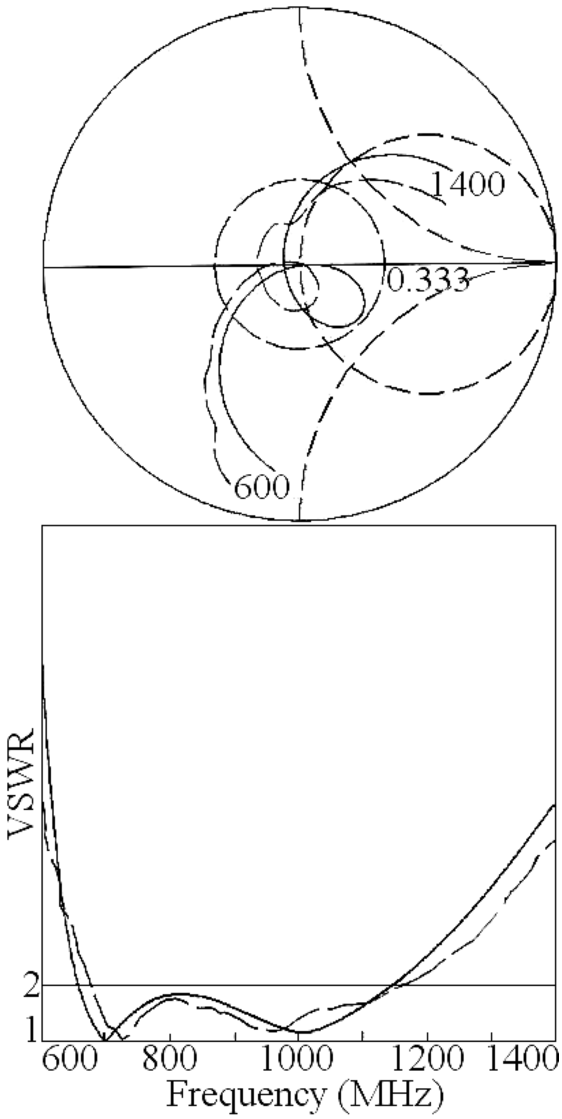

Fig 8: Input impedance and VSWR plots for pair of slots cut proximity fed shorted MSA, (——) simulated, (— —) measured

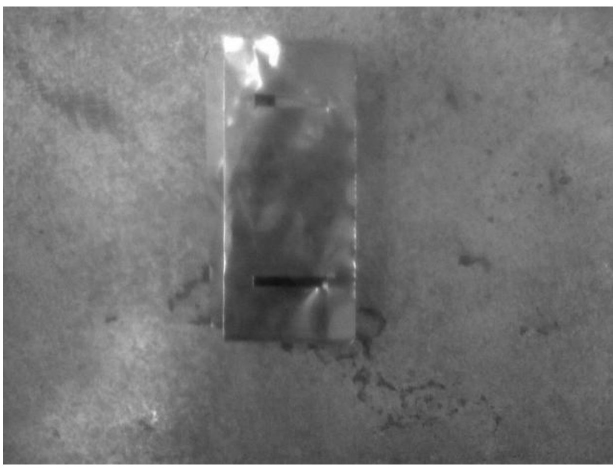

Fig 9: Fabricated prototype of shorted plate pair of rectangular slots cut proximity fed MSA

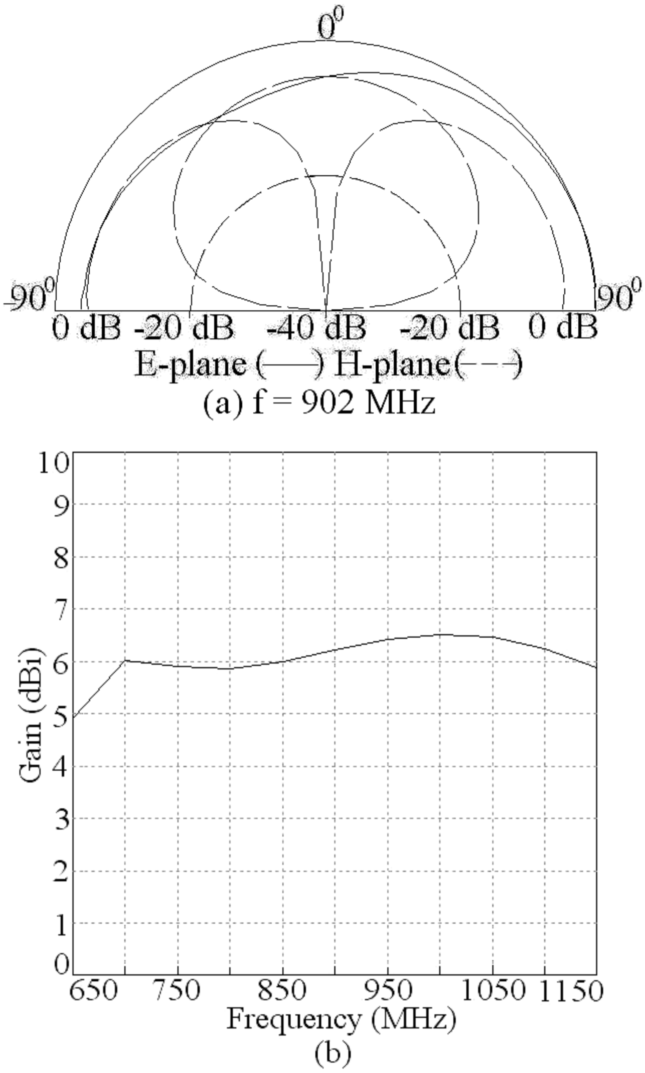

Fig 10: (a) Radiation pattern at center frequency and (b) gain variation over BW for shorted plate pair of slots cut proximity fed MSA

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