Broadband Proximity Fed Gap-coupled C-shaped Microstrip Antennas

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ABSTRACT
The C-shaped microstrip antenna is a compact variation of rectangular microstrip antenna and it has smaller bandwidth as compared to the rectangular patch. In this paper, bandwidth of C-shaped microstrip antenna is first increased by using proximity feeding technique. Further gap-coupled configuration of two C-shaped microstrip antennas on thicker substrate is proposed. It gives bandwidth of more than 300 MHz with broadside radiation pattern and gain of more than 5 dBi over most of the bandwidth. Further gap-coupled rectangular slot cut C-shaped microstrip antenna is proposed. This configuration yields bandwidth of more than 400 MHz.

Keywords
Broadband microstrip antenna, Compact microstrip antenna, C-shaped microstrip antenna, Orthogonal Higher order mode, Proximity feeding

1. INTRODUCTION
The compact C-shaped microstrip antenna (MSA) is realized by cutting the slot on one of the non-radiating edges of rectangular MSA (RMSA) [1]. It has smaller bandwidth (BW) and gain as compared to RMSA. The simplest method to increase the BW of MSA is by fabricating the patch on lower dielectric constant thicker substrate, and in most of the reported configurations, an air substrate (dielectric constant = 1) is used [1 – 3]. While using substrates of thickness more than $0.05\lambda_0$, proximity feeding technique has been used [4]. In proximity feeding, the coupling strip is either placed below the patch or it is placed in the plane of the patch. This controls the coupling between the patch mode and strip. The other simpler method to realize broadband MSA is by using multi-resonator gap-coupled configurations [1 – 3]. In these MSAs the parasitic patch having different resonance frequency is gap-coupled to the fed patch. The gap-coupled method increases the aperture area thereby increasing antenna gain. By maintaining the low profile nature of the MSA, the antenna BW is increased by cutting the slot at an appropriate position inside the slot [5]. In most of the reported configurations it is a general understanding that when the slot length is either equal to half wave or quarter wave in length then it introduces a mode near the fundamental mode resonance frequency of the patch to realize increased BW. But this simpler approximation of slot length against wavelength does not give accurate results while designing them at desired frequency. An analysis to study the effects of slot on broadband response in slot cut MSAs is reported [6]. For the equivalent MSA and slot cut MSA, resonance curve plot, surface current distributions and radiation pattern plots were studied. It was observed that the slot does not introduce any additional mode but reduces the resonance frequency of higher order modes of the patch, to realize broadband response.

In this paper, proximity fed C-shaped MSA is studied. The fundamental and higher order modes of the C-shaped patch are studied. A gap-coupled configuration of proximity fed C-shaped MSAs is proposed. This configuration optimized on thicker air substrate yields a BW of more than 300 MHz at center frequency of around 1000 MHz. The gap-coupled configuration gives broadside radiation pattern over the BW with a gain of more than 5 dBi. Further rectangular slot of equal lengths were cut on the edges of each of the C-shaped MSAs. The slot reduces the resonance frequency of orthogonal TM_{01} mode of each of the C-shaped patches and further along with TM_{10} modes of C-shaped MSAs, realizes broader BW of more than 400 MHz, at center frequency of around 1000 MHz. The slot cut gap-coupled antenna yields broadside radiation pattern over the BW with gain of more than 5 dBi. These configurations were first analyzed using IE3D software followed by experimental verifications [7]. The MSAs were fed using N-type connector of 0.32 cm inner wire diameter. In simulations, the antennas were analyzed using infinite ground plane. In measurements, antennas were fabricated using the copper plate having finite thickness and were suspended in air using the foam spacer supports which were placed towards the antenna corners. First to simulate the effect of an infinite ground plane, in measurements, a larger square ground plane of side length 100 cm is used. Further the antenna response is also validated using finite square ground plane of side length 20 cm. The antenna response was measured using R & S vector network analyzer. The radiation pattern was measured in minimum reflection surroundings with required minimum distance between the reference antenna and antenna under test [8]. The antenna gain was measured using three antenna method [8].

2. PROXIMITY FED C-SHAPED MSA
The proximity fed C-shaped MSA is shown in Fig. 1(a, b). For given outer patch dimension, resonance frequency of fundamental mode of C-shaped MSA depends upon slot dimension. The formulation for resonant length of C-shaped MSA is reported [1]. Using the same and for outer patch dimension of 10 x 5 cm, the slot dimensions are calculated such that it resonates in its TM_{10} mode at frequency of around 900 MHz. The C-shaped MSA is simulated and its resonance

curve plot is shown in Fig. 1(c). It shows two peaks and surface current distribution at them is shown in Fig. 1(d, e).

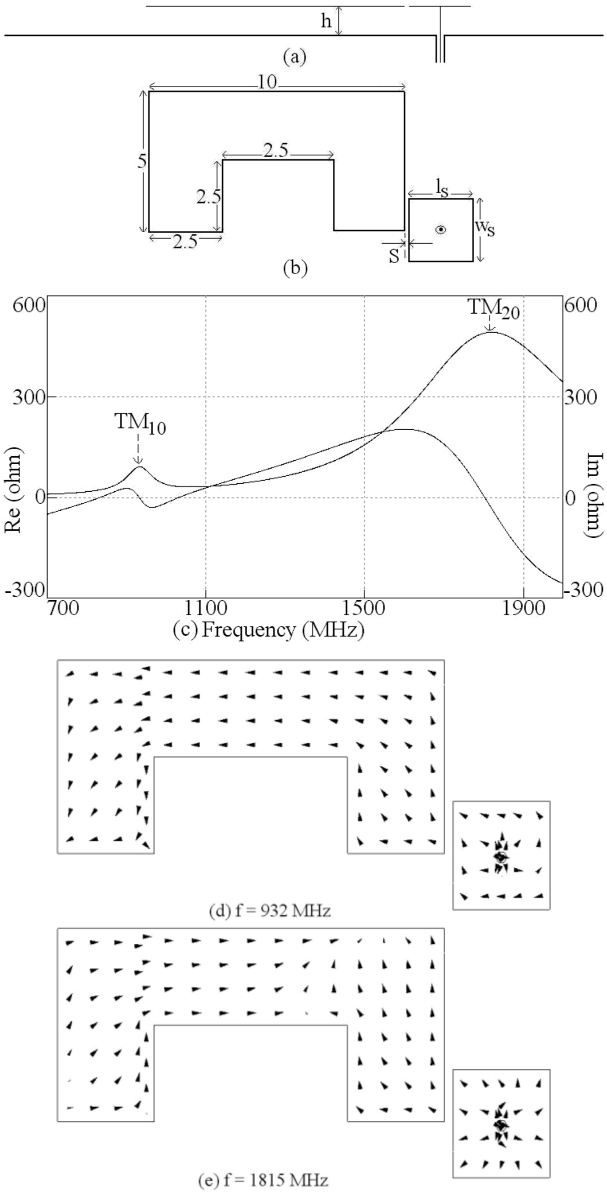

Fig. 1 (a) Top and (b) side views of proximity fed C-shaped MSA, its (c) resonance curve plot and its (d, e) surface current distribution at dual peaks

At first peak, surface current shows the distribution of TM_{10} mode. At second peak, the surface currents are varying along patch length and width. This is due to the close proximity of TM_{20} and orthogonal TM_{01} modes. The broadband response at TM_{10} mode is realized by using the parametric study for variations in substrate thickness for patch and coupling strip, strip dimensions and its spacing with respect to C-shaped patch. The MSA is optimized for substrate thickness of h = 3.6 cm ($0.12\lambda_0$) and its optimized input impedance plot, radiation pattern using finite square ground plane of side length 20 cm and gain variation over BW are shown in Fig 2(a – c), respectively. The simulated BW is from 848 to 1080 MHz (232 MHz, 24 %), whereas the measured BW is from 832 to 1072 MHz (240 MHz, 25%).

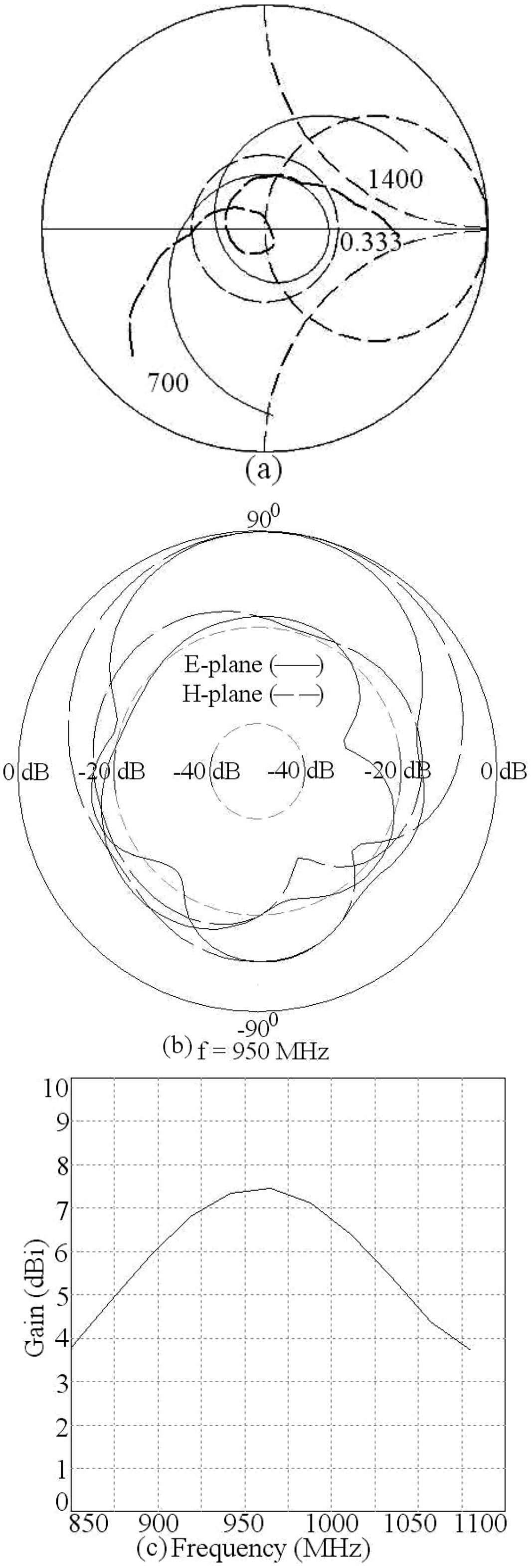

Fig. 2 (a) Input impedance plots, (—) simulated, (— —) measured, (b) radiation pattern at center frequency and (c) gain variation over BW for proximity fed C-shaped MSA

The radiation pattern is in the broadside direction with back-lobe radiation 15 dB down as compared to the main-lobe radiation. The antenna shows peak gain of nearly 7 dBi

3. PROXIMITY FED GAP-COUPLED C-SHAPED MSA

To enhance the BW, a parasitic C-shaped MSA is gap-coupled along the narrower edges of above proximity fed C-shape MSA as shown in Fig. 3(a). First another C-shaped MSA of equal dimension is gap-coupled along the smaller edges of C-shaped MSA. The resonance curve plots for varying length 'l_1' are shown in Fig. 3(b, c). For equal 'l_1' single peak in the resonance curve plot is present. With decrease in 'l_1' two peaks starts appearing in the resonance curve plot. The frequency due to 2nd C-shaped MSA increases with decrease in 'l_1'. For 'l_1' = 4.3 cm optimum BW is realized. The surface current distribution for optimum design is shown in Fig. 4(a, b). It shows 1st C-shaped MSA is resonant at first peak and 2nd one at second peak. The input impedance and VSWR plot for optimum design is shown in Fig. 4(c). The simulated BW is 318 MHz (31.8%, from 838 to 1154 MHz). The measurement was carried out and the BW is from 828 to 1148 MHz (320 MHz, 32.4%). The radiation pattern using finite ground plane and gain variation over the BW are shown in Figs. 5(a – c) and 6(a), respectively.

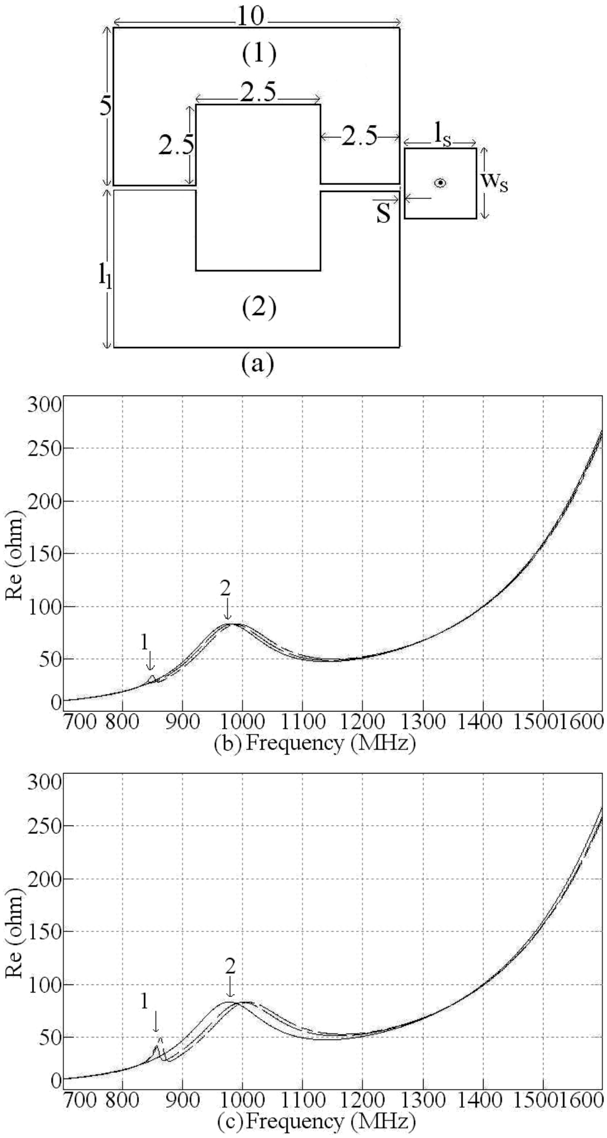

Fig. 3 (a) Proximity fed gap-coupled C-shaped MSAs and its resonance curve plot for 'l_1' = (b) (──) 5.0, (— —) 4.8, (— – —) 4.6, (c) (──) 5.0, (— —) 4.8, (— – —) 4.6

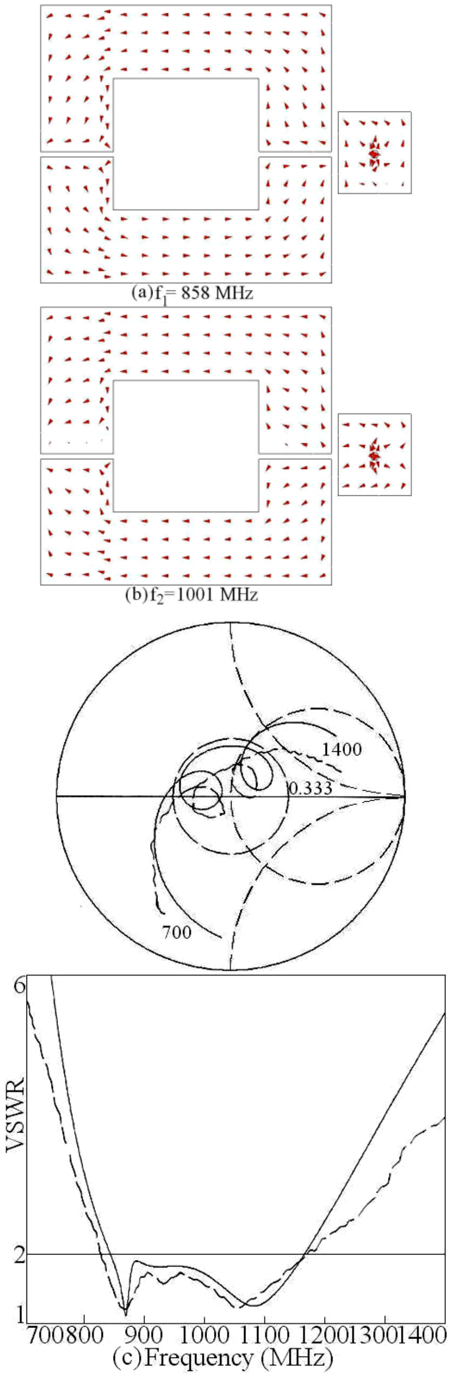

Fig. 4 (a, b) Surface current distribution at dual peaks and (c) input impedance and VSWR plots, (──) simulated, (— —) measured, for optimized proximity fed gap-coupled C-shaped MSAs

The pattern is in the broadside direction with E and H-planes are aligned along $\Phi = 0^0$ and 90^0, respectively. The antenna gain is more than 5 dBi over most of the BW. The fabricated prototype of the configuration is shown in Fig. 6(b). Further increase in the BW of gap-coupled C-shaped MSAs is realized by cutting equal length rectangular slots on the edge of C-shaped patch as shown in Fig. 6(c). The rectangular slot reduces the orthogonal TM_{01} mode resonance frequency on each of the C-shaped patches and along with TM_{10} mode on C-shaped MSAs yields broader BW of more than 400 MHz (~40%) with broadside radiation pattern with gain of more than 5 dBi over the complete BW.

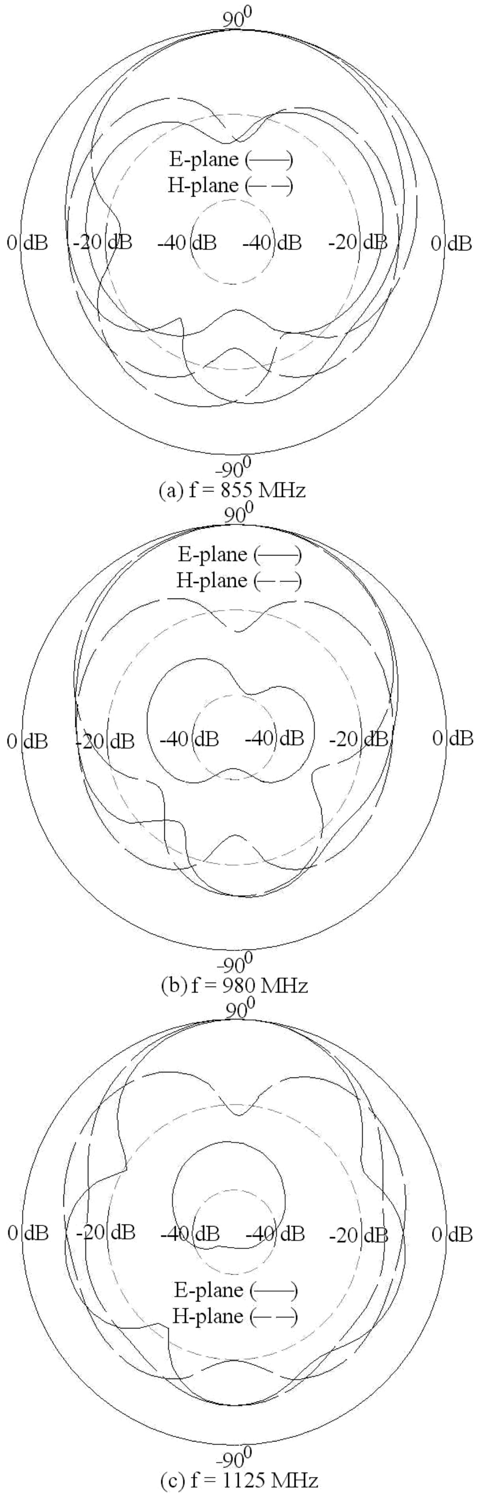

Fig. 5 (a – c) Radiation pattern over the BW for proximity fed gap-coupled C-shaped MSAs

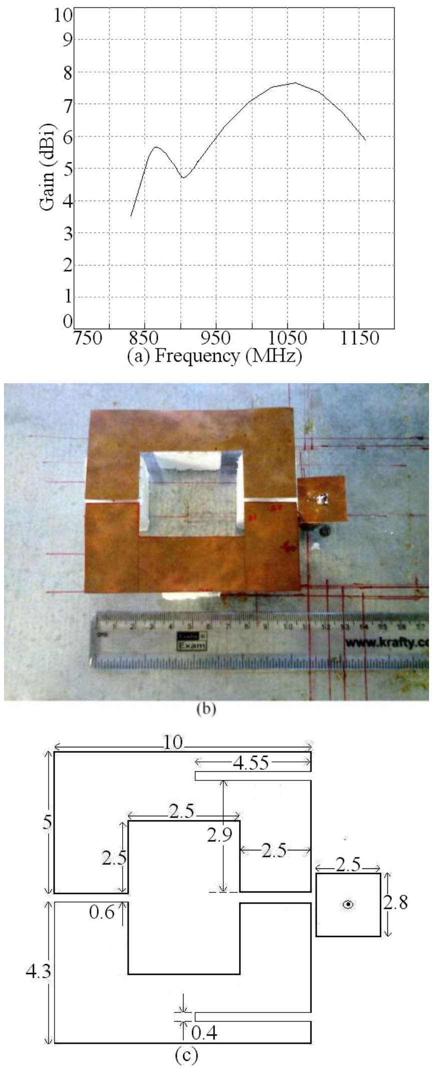

Fig. 6 (a) Gain variation over BW and (b) fabricated prototype of proximity fed gap-coupled C-shaped MSAs and (c) proximity fed gap-coupled rectangular slot cut C-shaped MSAs

4. CONCLUSIONS

The proximity fed C-shaped MSA on thicker air substrate is proposed. It gives BW of more than 200 MHz with broadside radiation pattern and gain of more than 5 dBi. Further gap-coupled configurations of C-shaped and slot cut C-shaped MSAs are proposed. The gap-coupled C-shaped MSAs yields BW of more than 300 MHz whereas slot cut gap-coupled C-shaped MSAs yields BW of more than 400 MHz. Both the configurations yields broadside radiation pattern with gain of more than 5 dBi over the entire BW.

5. REFERENCES

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