Broadband Proximity Fed Shorted 60^0 Sectoral Microstrip Antennas

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ABSTRACT
The broadband microstrip antenna is realized by fabricating the patch on lower dielectric constant thicker substrate followed by using proximity feeding technique. The proximity feeding technique realizes broader bandwidth for substrate thickness more than $0.06\lambda_0$. In this paper, proximity fed ETMSA is discussed. By placing the shorting plate along the zero field line at the fundamental mode of the patch, proximity fed compact shorted 60^0 sectoral MSA is proposed. It gives bandwidth of nearly 550 MHz at center frequency of nearly 1000 MHz. It shows radiation pattern with maximum in the end-fire direction and gain of more than 5 dBi over the bandwidth. Further by using symmetry of 60^0 sectoral patch, a compact half shorted 60^0 sectoral microstrip antenna is proposed. It gives simulated and measured bandwidth of 220 MHz with radiation pattern having maximum in end-fire direction and gain of more than 6 dBi over the entire VSWR BW.

Keywords
Broadband microstrip antenna, Compact microstrip antenna, Equilateral triangular microstrip antenna, Sectoral microstrip antenna, Proximity feeding

1. INTRODUCTION
The broadband microstrip antenna (MSA) is realized by fabricating the patch on thicker substrate having lower dielectric constant [1 – 3]. For substrate thickness more than 0.05 to $0.06\lambda_0$, different feeding techniques like, L-probe feed, proximity feed, has been used to realize larger bandwidth (BW) [4, 5]. Out of these two techniques, proximity feeding is simpler technique to implement for using thicker substrates. With the advent of personal mobile communication, the need for compact antenna has increased. The compact MSA is realized by placing the shorting post or plate along the zero field line at the fundamental mode of the patch [1 – 4]. The shorting technique converts the conventional half wavelength resonator into quarter wavelength resonator, which realizes half the patch size for given frequency. The compact MSA is also realized by cutting the slot at an appropriate position inside the patch [1 – 4]. The slot increases the length of surface currents at fundamental mode to reduce its frequency. However out of these two compact MSA techniques shorting post gives maximum reduction in resonance frequency whereas slot gives better radiation pattern and gain characteristics. The compact equilateral triangular MSA (ETMSA) is realized by placing the shorting post or plate along the zero field line at the fundamental TM_{10} mode of the patch. This results in shorted 60^0 sectoral MSA. This shorted MSA gives nearly 50% reductions in patch size as compared to ETMSA.

In this paper, fundamental and higher order modes of proximity fed ETMSA and shorted 60^0 sectoral MSAs are discussed. Further broadband proximity fed shorted 60^0 sectoral MSA is proposed. It yields simulated and measured BW of 550 MHz (> 45%). Since the shorted patch is used, the radiation pattern shows maximum in the end-fire direction with higher cross-polarization levels. The antenna has gain of more than 5 dBi over the entire VSWR BW. Further by using the symmetry of the shorted sectoral 60^0 MSA, a half shorted 60^0 sectoral MSA is proposed. This configuration yields BW of more than 200 MHz at center frequency of around 900 MHz. Although the patch size is half, this antenna shows gain of more than 6 dBi over most of the BW. These configurations were first analyzed using IE3D software followed by experimental verifications [6]. 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. The foam spacer has dielectric constant close to unity hence they do not affect the overall dielectric constant of the geometry. To simulate the effects of 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 [7]. The antenna gain was measured using three antenna method [7].

2. PROXIMITY FED ETMSAs AND SHORTED SECTORAL MSAs
The proximity fed ETMSA is shown in Fig. 1(a, b). To realize larger BW, substrate thickness of ‘h’ = 3.0 cm for patch is selected. By using equation (1), patch side length ‘S’ is calculated, such that it resonates in its fundamental TM_{10} mode at frequency of around 1000 MHz. The coupling rectangular strip is placed below the patch at substrate thickness of ‘h_1’ = 2.8 cm. The ETMSA is simulated using IE3D software and its resonance curve plot is shown in Fig. 1(d). It shows two peaks due to TM_{10} and TM_{11} modes at frequency of around 968 and 1867 MHz, respectively. The frequencies of various modes for this ETMSA calculated by using equation (1) are, f_{10} = 1010 MHz, f_{11} = 1749 MHz, f_{20} =

2020 MHz and f_{21} = 2672 MHz. The simulated resonance frequencies are closer to the calculated values. The surface current distribution at the above observed modes is shown in Fig. 1(e, f).

$$f_r = \frac{2c\sqrt{m^2 + mn + n^2}}{3S_e \pi \sqrt{\varepsilon_r}} \qquad (1)$$

where, c = 3 x 10^8 (m/s) : velocity of light in free space
m & n = mode indices

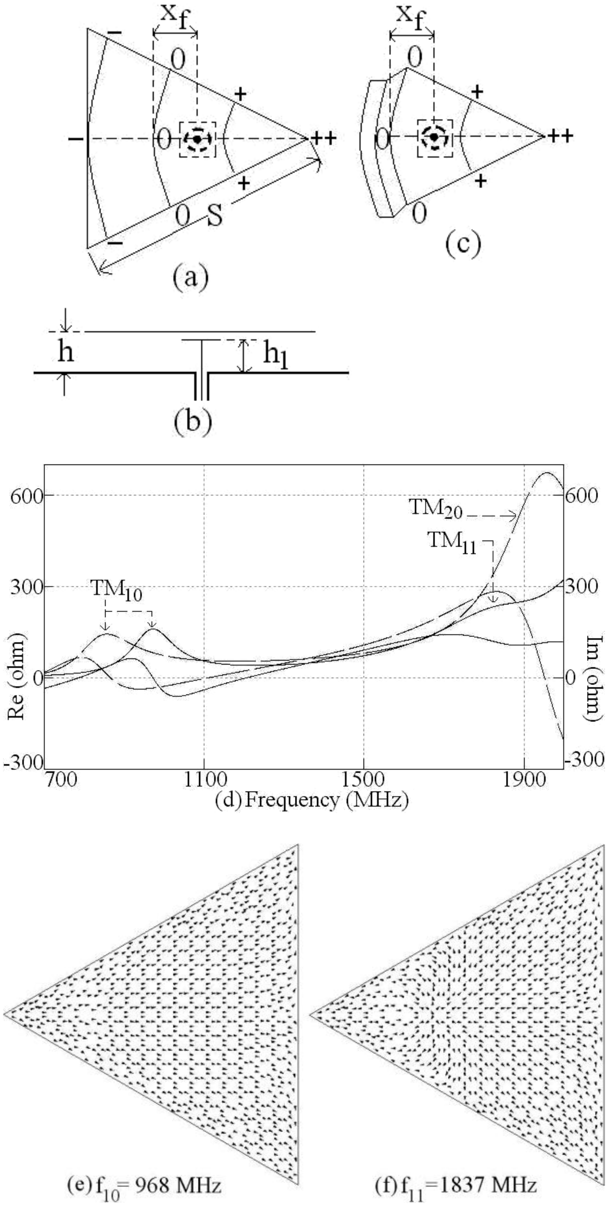


Fig. 1 (a) Top and (b) side views of proximity fed ETMSA, (c) proximity fed shorted 60^0 sectoral MSA, (d) resonance curve plot for (——) ETMSA, (— —) shorted 60^0 sectoral MSA and (e, f) surface current distributions at first two modes for proximity fed ETMSA

At TM_{10} mode surface currents shows one half wavelength variations along patch side length. The radiation pattern at TM_{10} mode is in the broadside direction. At TM_{11} mode, currents shows half wavelength variations from the centroid of the patch and towards the patch vertices, along the patch edges. The radiation pattern at TM_{11} mode is conical, i.e. maximum in end-fire direction. Further a compact shorted 60^0 sectoral MSA is realized by placing the shorting plate along the zero field line at the fundamental TM_{10} mode of ETMSA as shown in Fig. 1(c) and the resonance plot for the same is shown in Fig. 1(d). The plot shows two peaks due to TM_{10} (854 MHz) and TM_{20} (1953 MHz) modes. The surface current distribution at them is shown in Fig. 2(a, b). The current distribution shows one quarter and three quarter wavelength variations along the shorted patch length at the two frequencies, respectively.

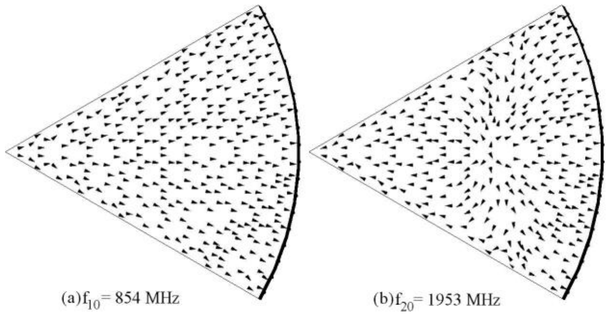


Fig. 2 Surface current distribution at shorted (a) TM_{10} and (b) TM_{20} modes for shorted 60^0 sectoral MSA

3. BROADBAND SHORTED SECTORAL MSAs

At fundamental shorted TM_{10} mode, the simulated input impedance locus for shorted 60^0 sectoral MSA for h = 3.0 cm, h_1 = 2.8 cm, and coupling strip of side length 1.6 cm, is shown in Fig. 3.

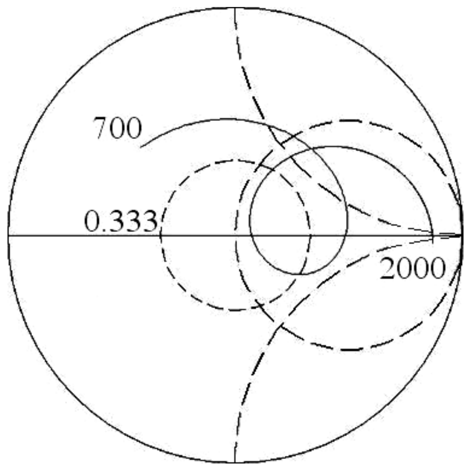
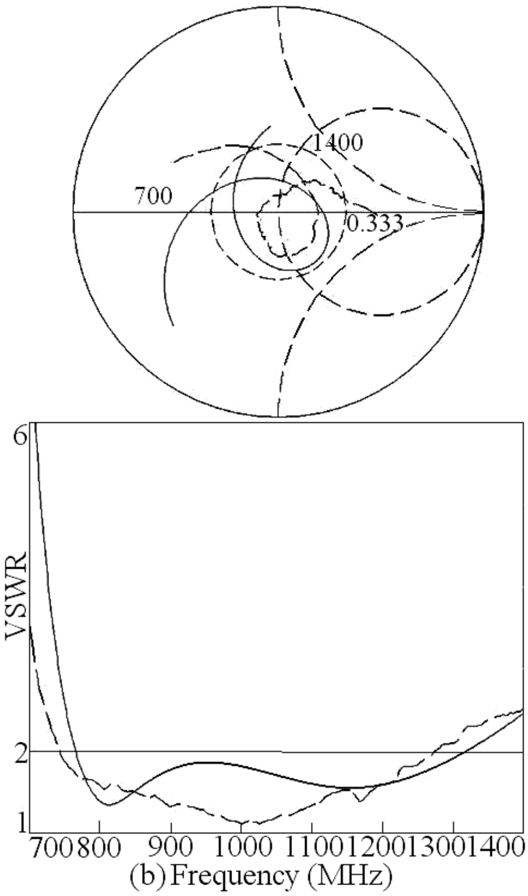
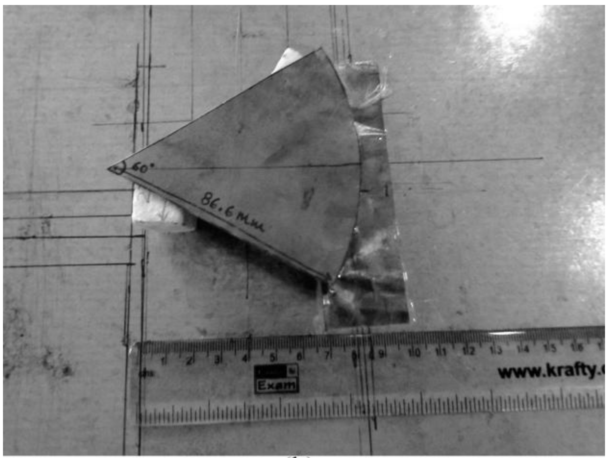


Fig. 3 Input impedance plot for proximity fed shorted 60^0 sectoral MSA

The loop position is not optimized for broadband response. To optimize the same, a parametric study for variations in coupling strip dimensions, its position below the patch and its substrate thickness is carried out. The broadband response is realized for h_1 = 2.0 and x_f = 4.2 cm as shown in Fig. 4(a). The simulated BW is from 766 to 1315 MHz (549 MHz, 50%). The experiment was carried out and the measured BW is from 784 to 1341 MHz (557, 49.6%). The fabricated prototype of the configuration is shown in Fig. 4(b). The radiation pattern over the BW using finite square ground plane of side length 20 cm is shown in Fig. 5(a – c). Due to the shorted patch, the pattern is nearly omni-directional with higher cross polarization levels over the entire BW. Over the complete BW the antenna gain is more than 5 dBi as shown in Fig. 6(a).

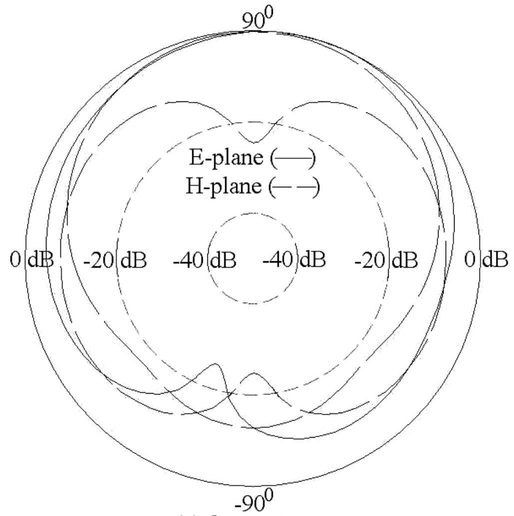




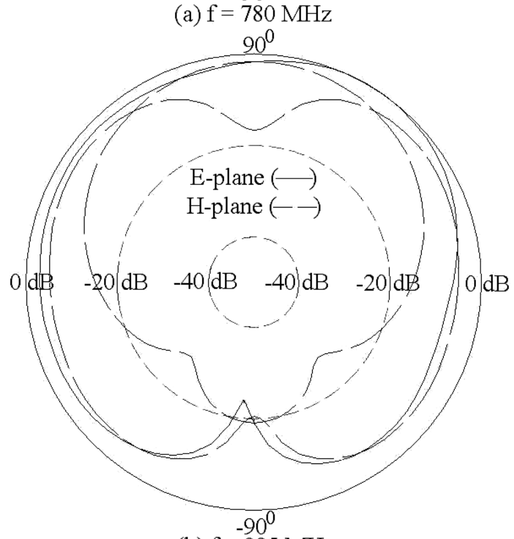
(b)

Fig. 4 (a) Input impedance and VSWR plots, (——) simulated, (— —) measured, and (b) fabricated prototype of proximity fed shorted 60^0 sectoral MSA

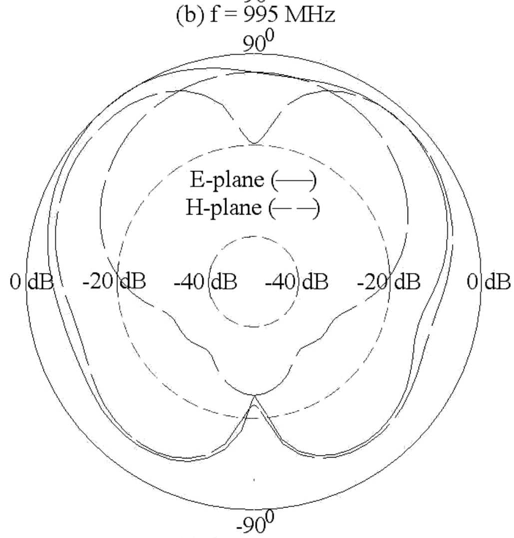
By using the symmetry of shorted 60^0 sectoral MSA, a half proximity fed shorted 30^0 sectoral MSA is proposed as shown in Fig. 6(b, c). To control the coupling between the strip and shorted patch, strip is placed in the same plane of the patch. By optimizing strip dimensions and gap between strip and patch, a broadband response as shown in Fig. 6(d) is obtained. The simulated BW is from 777 to 997 MHz (220 MHz (24.8%)) whereas the measured BW is from 751 to 980 MHz (229 MHz (26.4%)).



(a) f = 780 MHz



(b) f = 995 MHz



(c) f = 1210 MHz

Fig. 5 (a – c) Radiation pattern over BW for proximity fed shorted 60^0 sectoral MSA

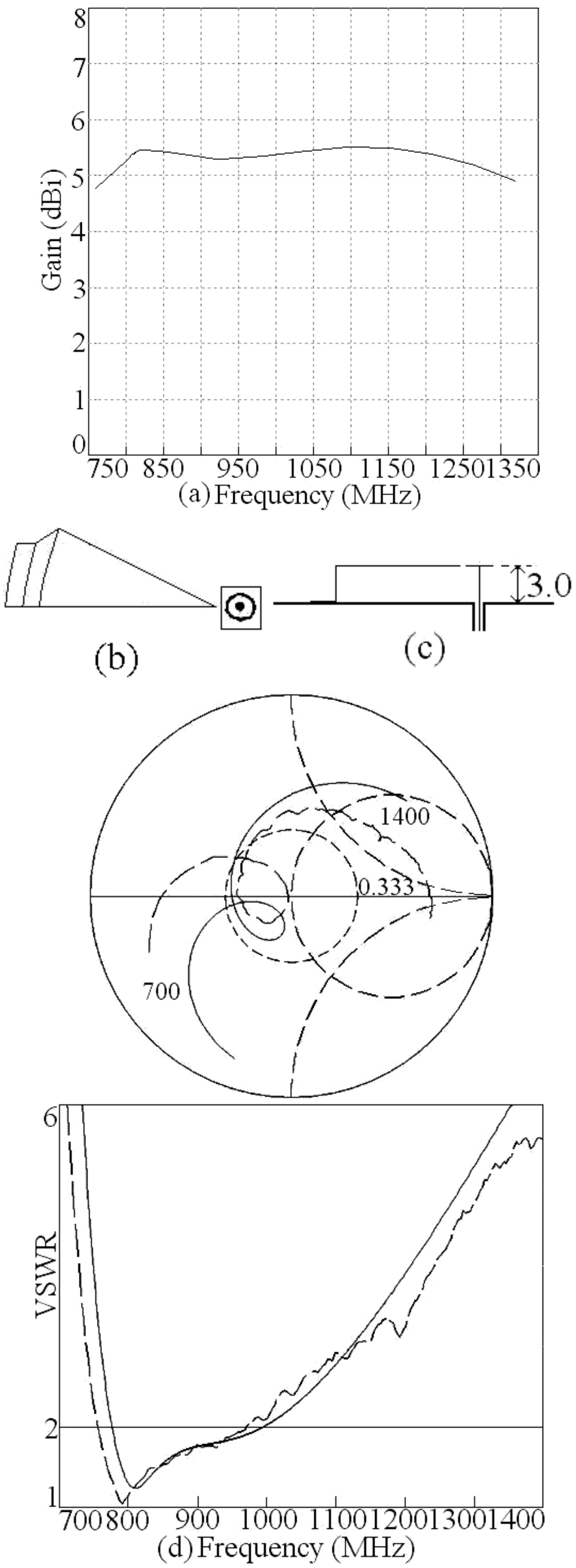


Fig. 6 (a) Gain variation over BW for proximity fed shorted 60^0 sectoral MSA, (b) top and (c) side views of proximity fed half shorted 60^0 sectoral MSA and its (d) input impedance and VSWR plots, (——) simulated, (— —) measured

The fabricated prototype of the configuration and radiation pattern over BW using finite ground plane is shown in Fig. 7(a – c). The antenna gain over BW is shown in Fig. 8.

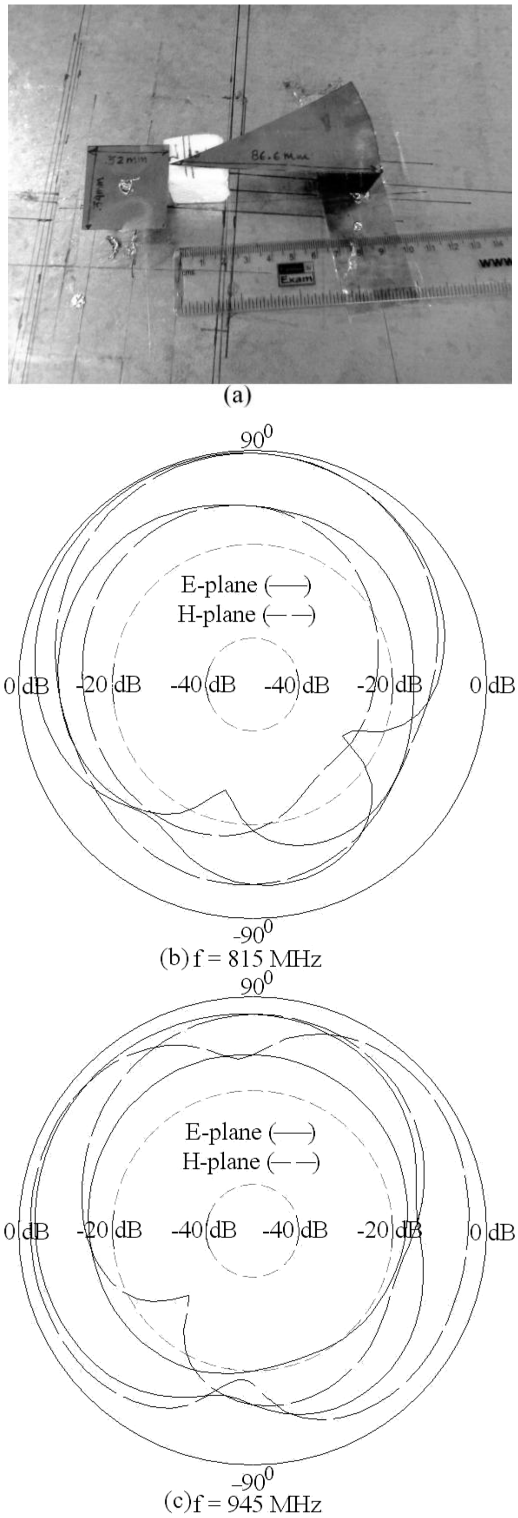


Fig. 7 (a) Fabricated prototype and (b, c) gain variation over BW for proximity fed shorted half 60^0 sectoral MSA

The pattern shows higher cross-polarization levels due to shorted patch. The antenna gain is more than 6 dBi over the complete BW. This is higher than that given by shorted 60^0 sectoral MSA. This is due to slight increase in effective patch area due to coupling strip and lower cross-polarization levels as compared to shorted 60^0 sectoral patch, over most of the BW.

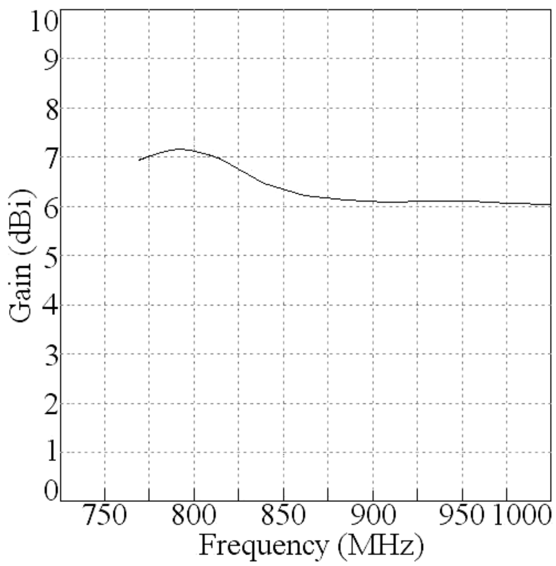


Fig. 8 Gain variation over BW for proximity fed shorted half 60^0 sectoral MSA

4. CONCLUSIONS

The fundamental and higher order modes of proximity fed ETMSA and shorted 60^0 sectoral MSA are discussed. The broadband variations of shorted 60^0 sectoral MSA and half shorted 60^0 sectoral MSA are proposed. The shorted 60^0 sectoral MSA gives BW of nearly 550 MHz (50%) with gain of more than 5 dBi over the complete BW. The shorted half 60^0 sectoral MSA gives BW of 220 MHz (24%) with gain of more than 6 dBi over the complete BW. Although the area of half shorted 60^0 MSA is reduced by 50%, slight increase in its gain is due to overall lower cross-polarization levels over most of the BW and slight increase in aperture area due to the coupling rectangular strip, which is being in the same plane of the shorted patch.

5. REFERENCES

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