ISSN 2320 2599
Volume 2, No.1, January – February 2013
International Journal of Microwaves Applications
Available Online at http://warse.org/pdfs/2013/ijma03212013.pdf

Broadband Gap-coupled Proximity fed U-slot cut Rectangular Microstrip Antennas

Amit A. Deshmukh, Apurva A. Joshi and Ankita R. Jain
1. EXTC, DJSCOE, Vile – Parle (W), Mumbai, India, Email – draadeshmukh@djscoe.org

ABSTRACT

Broadband proximity fed U-slot cut rectangular microstrip antenna is proposed which yields bandwidth of more than 360 MHz (> 35%) with broadside radiation pattern and gain of more than 7 dBi. To increase the gain and bandwidth, a gap-coupled configuration of U-slot cut rectangular microstrip antenna with two rectangular microstrip antennas is proposed. This configuration yields bandwidth of more than 450 MHz (>45%) with broadside radiation pattern and gain of more than 9 dBi. To Further increase the gain, rectangular patches were gap-coupled along both the edges of U-slot cut patch which yields bandwidth of nearly 480 MHz (>50%) with an increased peak gain of more than 11 dBi. The proposed antennas optimized in 1000 MHz frequency band, can find applications in mobile communication environment.

Key words: Rectangular microstrip antenna, Broadband microstrip antenna, U-slot, Proximity feeding

1. INTRODUCTION

The broadband microstrip antenna (MSA) is realized by cutting slot inside the patch, which is fabricated on lower dielectric constant thicker substrate in conjunction with the proximity feeding technique [1 – 7]. The slot is said to introduce a mode near the fundamental mode of the patch and realizes broadband response. The proximity feeding technique realizes impedance matching while using thicker substrates (i.e. more than $0.06\lambda_0$). In most of the reported broadband slot cut configurations, radiating patch is suspended in air, thereby realizing dielectric constant of unity. The slot cut MSAs yields bandwidth (BW) of more than 30% when designed at frequencies around 1000 MHz and a BW of more than 45 to 50% when designed at frequencies above 3 to 5 GHz. Depending upon the frequency range in which the MSA is designed, slot cut single patch element gives gain of more than 6 to 7 dBi. The antenna gain is increased by using gap-coupled configurations (which increases the overall patch size) or by using the individual antenna elements in an array configuration [8]. The gain of slot cut MSAs is increased by using arrays of slot cut patches [9, 10]. In these arrays, microstrip line power divider network are used to feed the individual antenna elements. The power divider network is complex in design and the losses in them reduce antenna gain. Also these configurations have narrower BW (< 30%) as BW is governed by the fed antenna.

In this paper, first a broadband proximity fed U-slot cut rectangular MSA (RMSA) on air substrate of thickness (h) 3 cm ($0.09\lambda_0$) is proposed. It gives simulated and measured BW of more than 360 MHz (>35%) with broadside radiation pattern and gain of more than 7 dBi over the BW. To further increase the gain and BW of U-slot cut RMSA, a gap-coupled technique is used and two equal dimension RMSAs are gap-coupled along the radiating edges of U-slot cut RMSA. This gap-coupled configuration yields BW of more than 450 MHz (>45%) with broadside radiation pattern and gain of more than 9 dBi. Further increase in gain of this gap-coupled configuration is realized by gap-coupling parasitic RMSAs along both the radiating and non-radiating edges of proximity fed U-slot cut RMSA. This configuration realizes BW of more than 480 MHz (50%) with broadside radiation pattern and peak gain of more than 11 dBi. These broadband MSAs have been first optimized using IE3D software followed by experimental verifications [11]. The dimensions of the patches were optimized such that they cover 800 – 1200 MHz frequency band. The air substrate is used to maximize the radiation efficiency. In the measurements the antennas were fabricated using copper plate having finite thickness (which is also considered in simulation) and were suspended in air using foam spacer support placed towards the antenna corners. The foam spacers were also used to maintain required air gap between fed and parasitic RMSAs. The antenna is fed using N-type connector of 0.32 cm inner wire diameter. The measurement was carried out using R & S vector network analyzer using square ground plane of side length 60 cm ($2.0\lambda_0$). The radiation pattern was measured in minimum reflection surrounding with the required minimum far field distance between the reference antenna and the antenna under test [12]. The antenna gain was measured using three antenna method [12].

2. PROXIMITY FED U-SLOT CUT RMSA

The proximity fed U-slot cut RMSA is shown in Fig. 1(a, b). To realize larger BW, thicker air substrate (h = 3.0 cm) is selected. The U-slot introduces resonant mode near TM_{10} mode frequency of the patch and yields broader BW. To control the coupling between patch and slot mode, coupling strip is placed inside the slot which is cut in the patch. By optimizing U-slot dimension and strip position, a broadband response is realized. Since two resonant modes are present in slot cut RMSA, two loops in the input impedance locus and two peaks in the resonance curve plots are present, as shown in Figs. 1(c) and 2, respectively. The first peak in the resonance curve is due to patch TM_{10} mode. The second peak is due to mode introduced by U-slot, as the surface current at this frequency are circulating around the U-slot. The simulated BW is 372 MHz (39%) whereas the measured BW is 362 MHz (38.4%). The antenna has broadside radiation pattern with gain of more than 7 dBi.

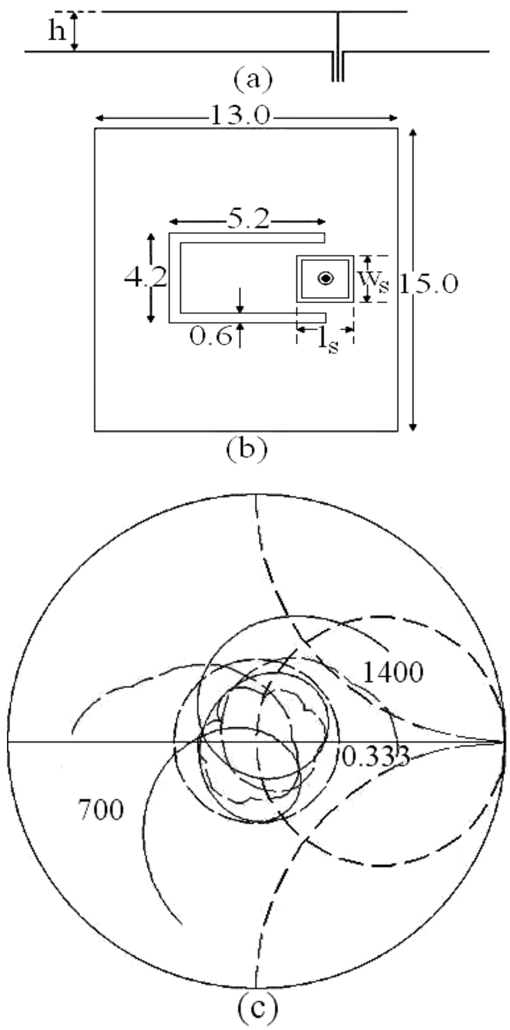


Figure 1 (a) Side and (b) top views of proximity fed U-slot cut RMSA and its (c) input impedance plot, (——) simulated, (— —) measured

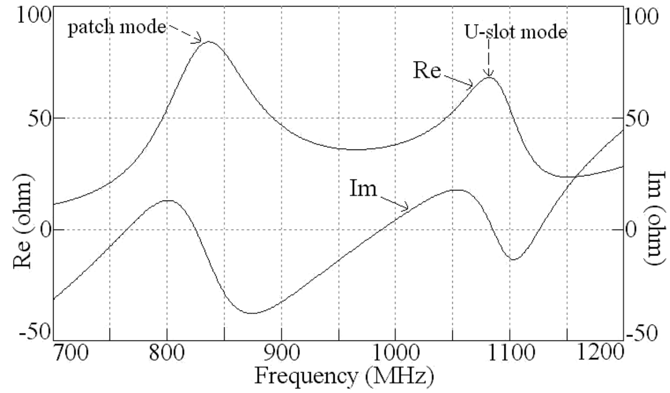


Figure 2 Resonance curve plot for proximity fed U-slot cut RMSA

To further increase the BW and gain, RMSAs of equal dimensions are gap-coupled along the radiating and non-radiating edges of U-slot cut RMSA as discussed in the following section.

3. BROADBAND GAP-COUPLED U-SLOT CUT RMSA

The parasitic RMSAs of equal dimensions are gap-coupled along the radiating edges of proximity fed U-slot cut RMSA as shown in Fig. 3(a). To realize different resonance frequencies, length of gap-coupled RMSAs is taken to be smaller than U-slot cut RMSA length. Thus three resonance frequencies are present in this configuration as shown in its resonance curve plot in Fig. 3(b). The dimensions of parasitic RMSAs were optimized such that the loop formed due to coupling between the modes of fed and parasitic patches lies inside VSWR = 2 circle, as shown in Fig. 4(a).

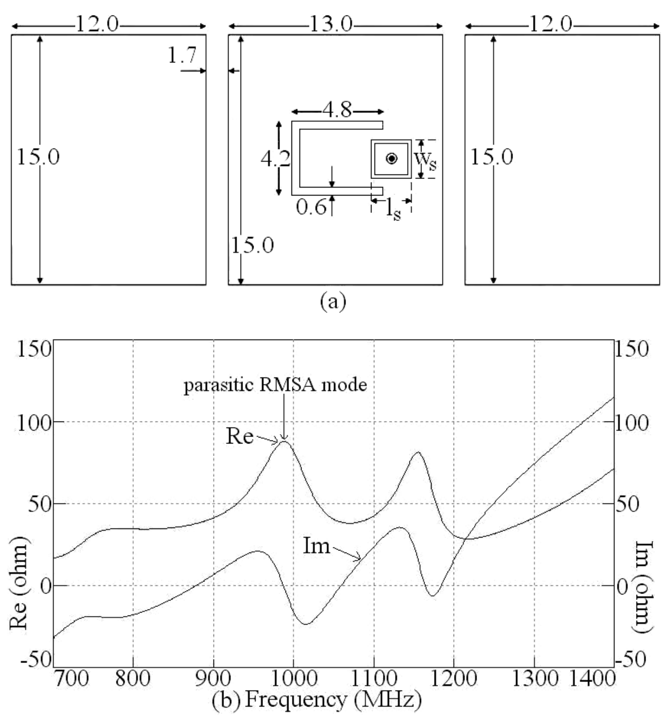
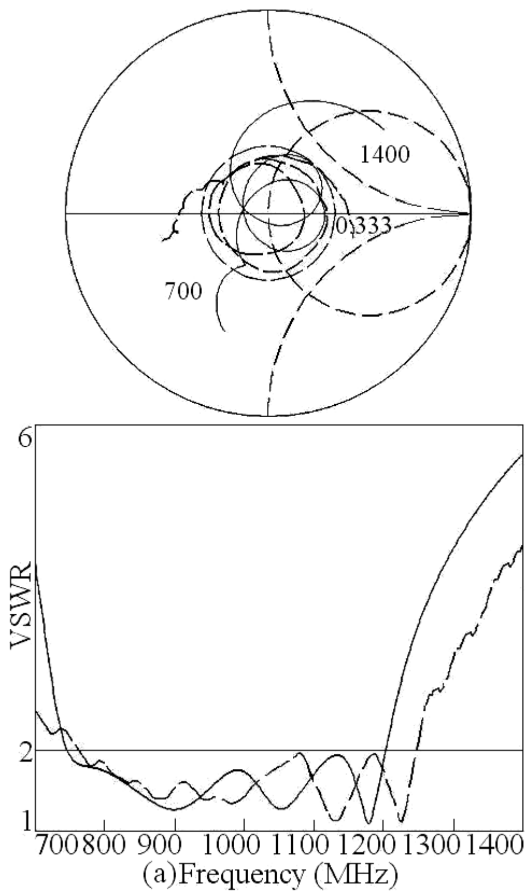
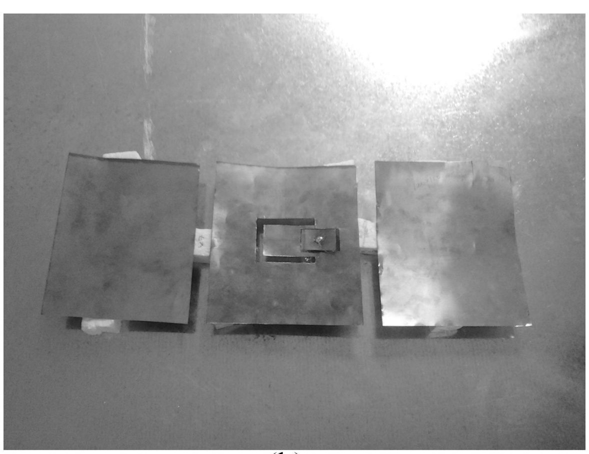


Figure 3 (a) Proximity fed U-slot cut RMSA gap-coupled to RMSAs and its (b) resonance curve plot

The simulated BW is 453 MHz (46.4%). The antenna was fabricated using copper plate having finite thickness and it was suspended in air using the foam spacers support placed towards antenna corners. The foam spacers were also used to maintain the required air gap between fed and parasitic patches. The measurement was carried out using square ground plane of side length 60 cm. The measured BW is 470 MHz (47.5%) as shown in Fig. 4(a). The fabricated prototype of the gap-coupled configuration is shown in Fig. 4(b).





(b)

Figure 4 (a) Input impedance and VSWR plots, (—) simulated, (— —) measured and (b) fabricated prototype of proximity fed U-slot cut RMSA gap-coupled to RMSAs

The radiation pattern and gain variation over the BW using finite ground plane are shown in Figs. 5(a – c) and 6(a), respectively.

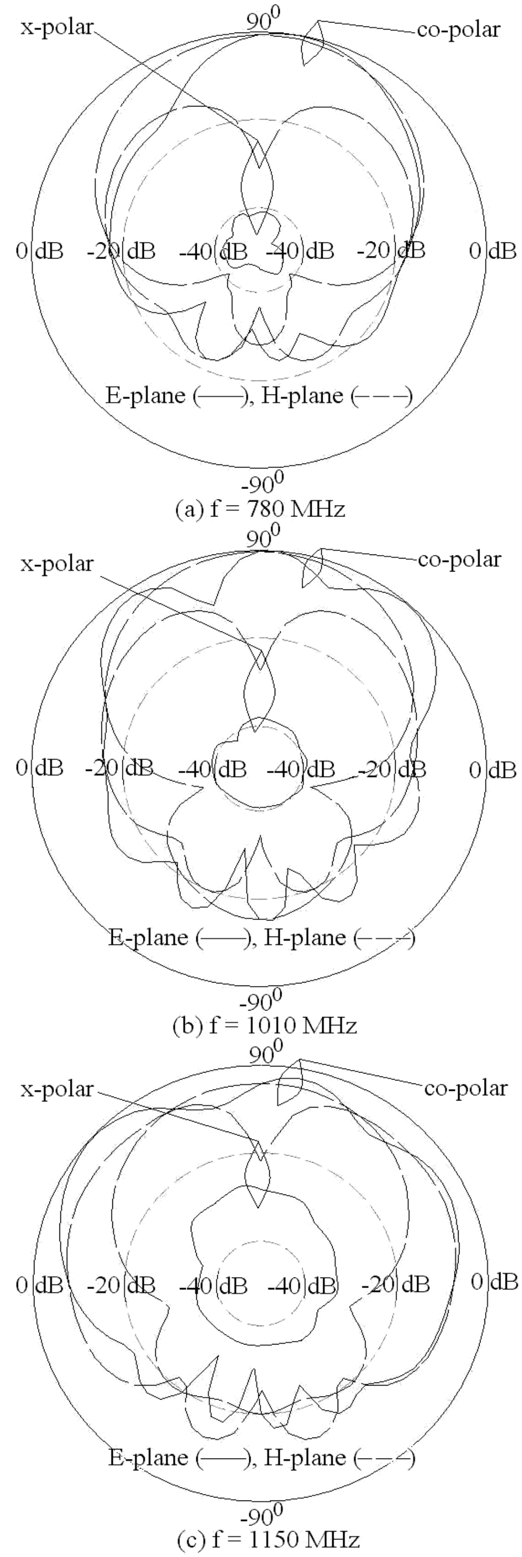


Figure 5 (a – c) Radiation pattern over BW for proximity fed U-slot cut RMSA gap-coupled to RMSAs

The pattern is in the broadside direction with higher cross-polarization levels towards the higher frequencies of BW. Using 60 cm square ground plane the back-lobe radiation remains 15 dB down as compared to main lobe radiation. The antenna gain remains more than 9 dBi over most of the BW. To further increase the gain, parasitic RMSAs were gap-coupled along the non-radiating edges of the above gap-coupled configuration as shown in Fig. 6(b). The dimensions of parasitic RMSAs along the individual co-ordinate axis were taken to be the same.

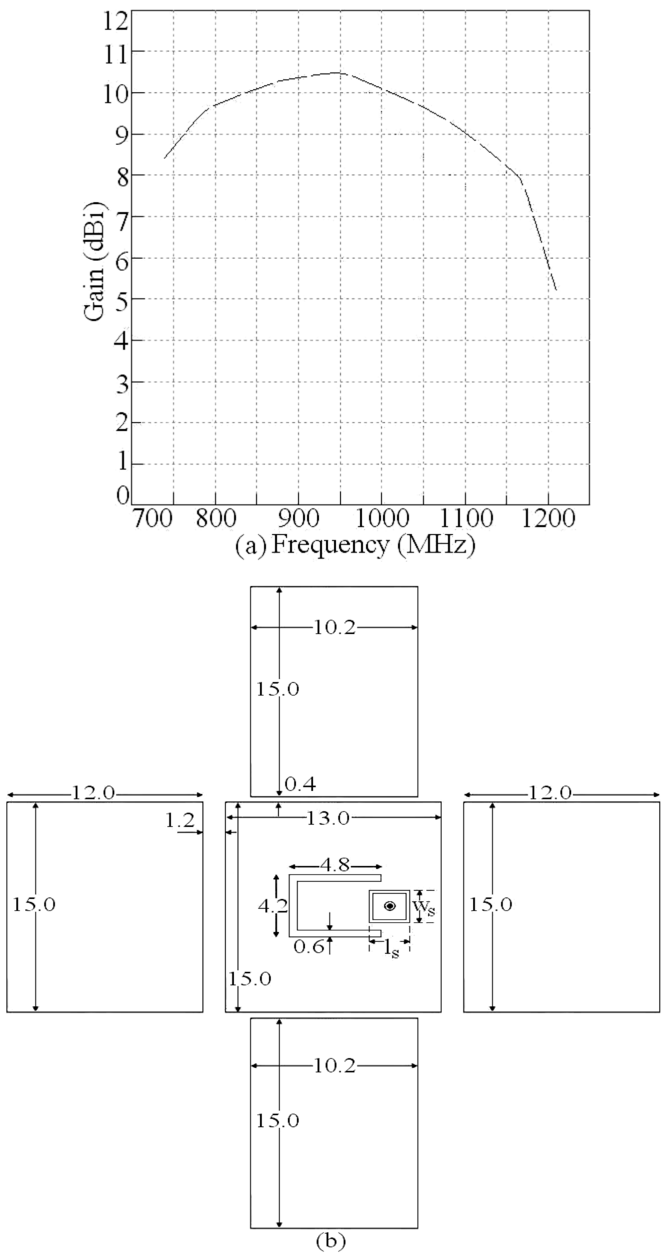


Figure 6 (a) Gain variation over BW for proximity fed U-slot cut RMSA gap-coupled to RMSAs and (b) proximity fed U-slot cut RMSA gap-coupled to four RMSAs

The optimized broadband response for this gap-coupled configuration is shown in Fig. 7(a). The simulated BW is 485 MHz (50.4%) whereas the measured BW is 496 MHz (51.2%). The fabricated prototype of the gap-coupled configuration is shown in Fig. 7(b). The radiation pattern over the BW is shown in Fig. 8(a – c).

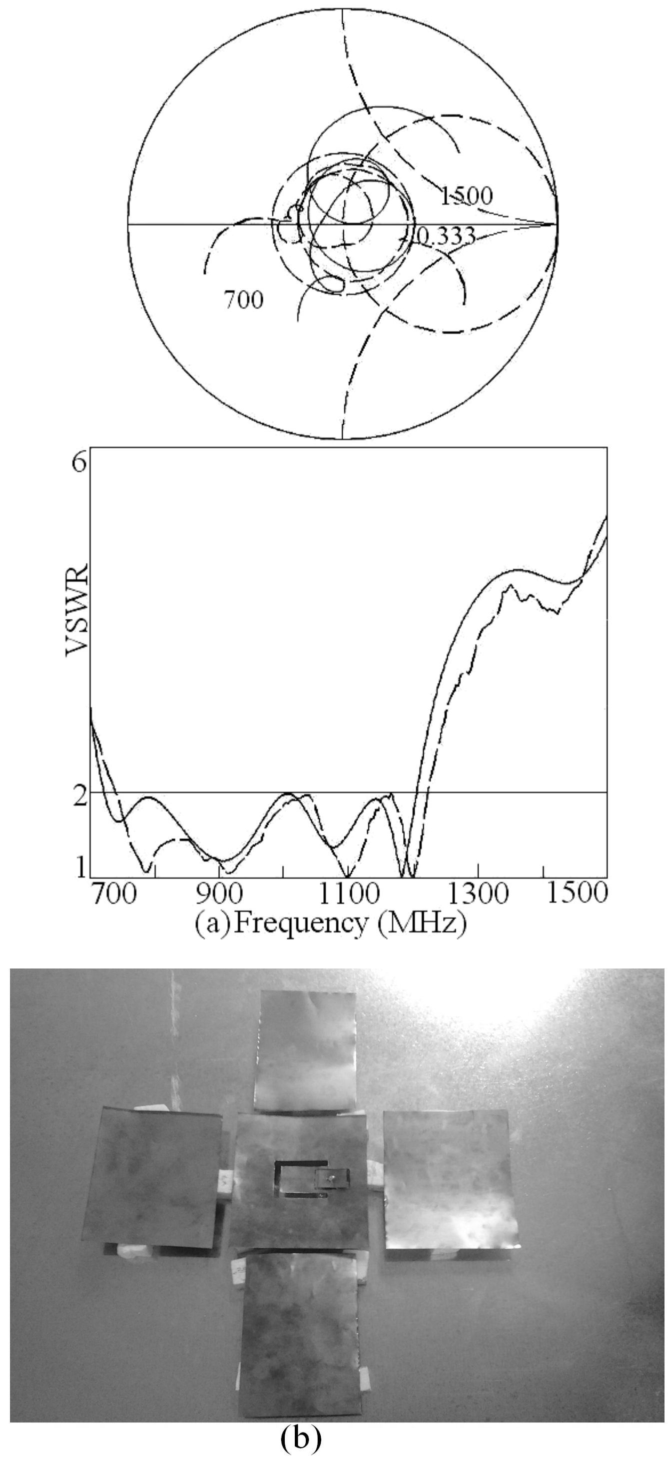


Figure 7 (a) Input impedance and VSWR plots, (——) simulated, (— —) measured and (b) fabricated prototype of proximity fed U-slot cut RMSA gap-coupled to RMSAs along both the edges

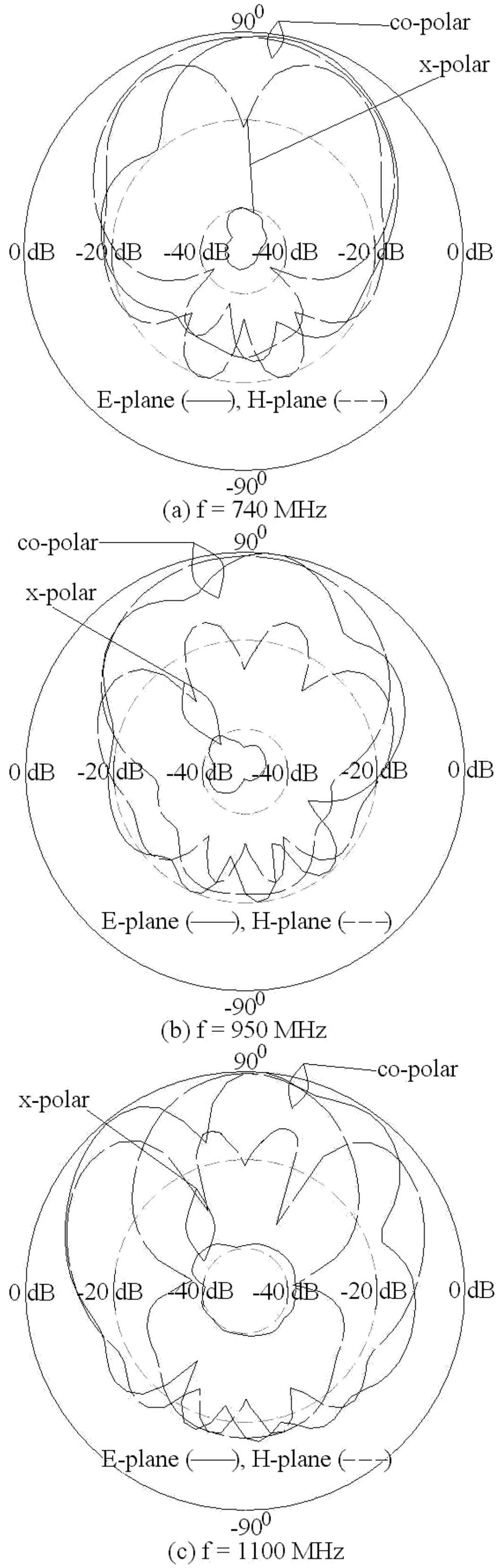


Figure 8 (a – c) Radiation pattern over the BW for proximity fed U-slot cut RMSA gap-coupled to RMSAs along both the edges

The pattern is in the broadside direction with higher cross-polarization levels towards the higher frequencies of BW. The back-lobe radiation is less than 15 dB as compared to main lobe of radiation over the complete BW. The antenna gain is shown in Fig. 9. Over most of the BW, the antenna has gain of more than 9 dBi with peak gain more than 11 dBi.

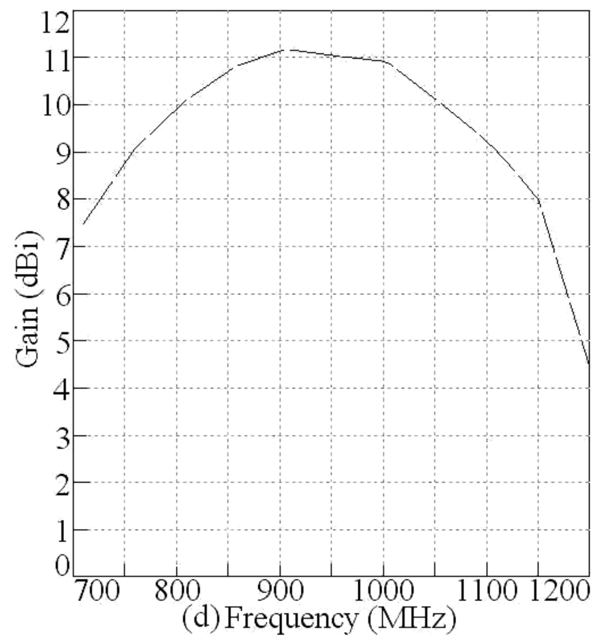


Figure 9 Gain variation over BW for proximity fed U-slot cut RMSA gap-coupled to RMSAs along both the edges

The cross-polar level increases in both the gap-coupled configurations for frequencies above 1200 MHz which is due to the excitation of higher order and orthogonal modes in the parasitic RMSAs. With BW of more than 450 MHz and gain of more than 9 dBi, the proposed configurations can find applications in mobile communication environment in 800 – 1200 MHz frequency band. While using these antennas in practical applications, the patches will be covered with protective cover which will give rise to radome effect. This radome effect is not considered in the present analysis. However for further studies of these gap-coupled configurations, the radome effect simulating the protective cover can be considered.

4. CONCLUSION

The proximity fed U-slot cut RMSA is proposed which gives the BW of more than 350 MHz in the 1000 MHz frequency band. Further to increase the gain and BW of U-slot cut RMSA, gap-coupled configuration with parasitic RMSAs is proposed. The gap-coupled configuration with two RMSAs gives BW of nearly 450 MHz whereas with four RMSAs it gives BW of nearly 500 MHz with broadside radiation pattern and gain of more than 9 dBi over most of the BW.

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