Broadband Slot Cut Modified Rectangular Microstrip Antenna

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ABSTRACT
The broadband microstrip antenna is realized by cutting a slot at an appropriate position inside the slot. The slot introduces a mode near the fundamental resonance frequency of the patch and realizes broadband response. The broadband patch antenna is also realized by using the proximity feeding technique. Using substrate of thickness greater than $0.08\lambda_0$, the bandwidth of slot cut patch antennas is increased by using proximity feeding technique. In this paper, a proximity fed broadband rectangular microstrip antenna is discussed. Further the proximity fed broadband two pairs of rectangular slot cut rectangular microstrip antenna is proposed. The pair of vertical and horizontal slots were cut inside and on the non-radiating edges of the patch. These slots modify the higher order TM_{02} and TM_{12} mode resonance frequencies of the patch and realize broadband response. A bandwidth of more than 430 MHz with broadside radiation pattern over the operating bandwidth with a gain of 8 dBi is obtained. The design is proposed in 900 MHz frequency band and due to the above antenna characteristics this antenna finds an application in mobile communication environments.

Keywords
Rectangular microstrip antenna, Broadband microstrip antenna, Proximity feeding, pair of rectangular slot

1. INTRODUCTION
The broadband microstrip antenna (MSA) is realized by fabricating the patch on thicker substrate having lower dielectric constant [1 – 3]. This substrate reduces the quality factor of the cavity below the patch and thereby yields larger bandwidth (BW). For the substrates having thickness greater than $0.04\lambda_0$, the probe length increase which increases the probe inductance and it limits the antenna BW. A simpler feeding technique like proximity feeding is used for substrate thickness greater than $0.06\lambda_0$ [4]. In the proximity feeding method, the coupling strip is either kept below the patch or it is placed inside the slot which is cut in the patch or it is placed in the same plane of the patch and very closer to its edge and due to the electromagnetic coupling between the patch mode and the strip, a BW is increased [5].
These slots introduce a mode near the fundamental mode of the patch (i.e. TM_{10} in rectangular MSA, TM_{11} in circular MSA, and TM_{10} in equilateral triangular MSA) and realize broadband response. These broadband slot cut MSAs are optimized for substrate thickness of $0.06\lambda_0$ to $0.08\lambda_0$. For substrate thickness greater than $0.08\lambda_0$, the BW is limited by the probe inductance. The BW for substrate thickness greater than $0.08\lambda_0$ is increased by using the proximity feeding technique [9]. The radiation pattern in rectangular MSA (RMSA) at its fundamental TM_{10} mode is in the broadside direction whereas the pattern at higher order modes like TM_{20} and TM_{02} is in the conical directions. These slot cut probe fed or proximity fed broadband antennas realized by coupling between the fundamental patch mode and the mode introduced by the slots have broadside radiation pattern over the operating BW.

In this paper, a broadband proximity fed rectangular MSA (RMSA) is discussed. The coupling strip is kept in the same plane of the patch and close to the patch radiating edge. This proximity fed configuration gives a simulated BW of nearly 190 MHz (20%) whereas the measured BW is 195 MHz (20.6%). Further a broadband pair of rectangular slots cut proximity fed RMSA is proposed. The pair of rectangular slots is cut along the patch length as well as on both the non-radiating edges of the RMSA. The analysis for this slot cut RMSA was carried out over a wide frequency range. The position of these slots were decided such that they modifies the higher order orthogonal TM_{02} and TM_{12} modes resonance frequency of the patch and yields a broadband response. The BW of more than 430 MHz at center frequency of around 1100 MHz is realized. The slots modify the directions of surface currents on the patch at TM_{02} and TM_{12} modes and the currents are aligned along the patch length. Therefore the proposed antenna gives broadside radiation pattern over the operating BW. To realize higher gain, the antenna is optimized on air substrate. The proximity fed antennas were first analyzed and optimized using the IE3D software wherein the infinite ground plane is used [10]. Further the measurements were carried out. In the measurements, to simulate the infinite ground plane effect a ground plane size of more than six times the substrate thickness in all the directions with respect to the patch dimension was taken [1]. The antenna is fabricated using the copper plate and it was supported in air using the foam spacer support which was placed towards the antenna corners. The N-type connector of inner wire diameter 0.32 cm is used to feed the antenna. The measurement was carried out using HP vector network analyzer. The radiation pattern was measured in the minimum reflection surroundings with required minimum far field distance between the reference antenna and the antenna under test [11]. The antenna gain is measured using three antenna method.

2. PROXIMITY FED RMSA
The broadband proximity feed RMSA is shown in Figure 1(a, b). The patch and the coupling strip are kept in the same plane and to realize larger gain and BW, air substrate of thickness 3.0 cm ($0.09\lambda_0$) is used. To optimize the configuration, a parametric study by varying strip dimensions (l, w), spacing between the patch and strip (s), and the substrate thickness (h) is carried out and the input impedance loci for them are shown in Figure 2(a, b). The impedance locus is capacitive for smaller ‘h’ as shown in Figure 2(a) and hence in those cases a broader BW cannot be realized. With an increase in strip length (l) (which increases the strip area) the loop size increases which increases the BW, as shown in Figure 2(b).

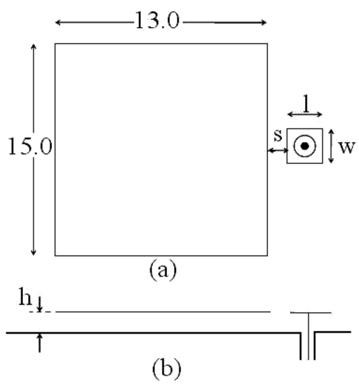

Fig 1: (a) Top and (b) side views of proximity fed RMSA

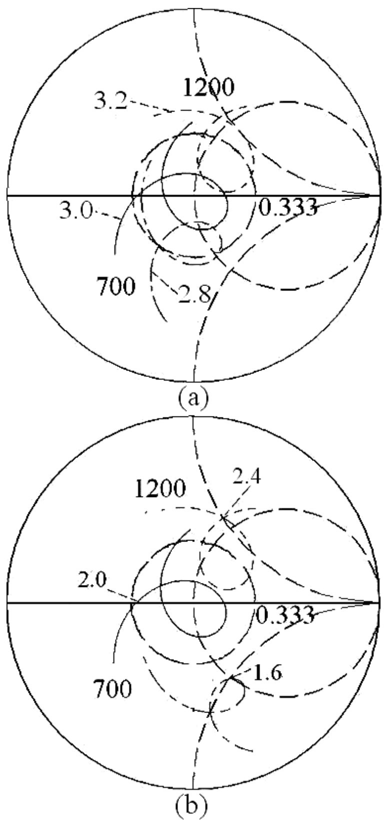

Fig 2: (a, b) Input impedance locus for variation in different parameters for proximity fed RMSA

However for larger l, the loop does not lie completely inside the VSWR = 2 circle, which decreases the BW. Also the loop rotates in the clockwise direction in the smith chart, due to the decreased capacitive impedance. A similar behavior is observed for variations in w. The variation in ‘s’ changes the coupling between the patch mode (TM_{10}) and strip. For the dimensions shown in Figure 3(a), the optimized input impedance plot is shown in Figure 3(b).

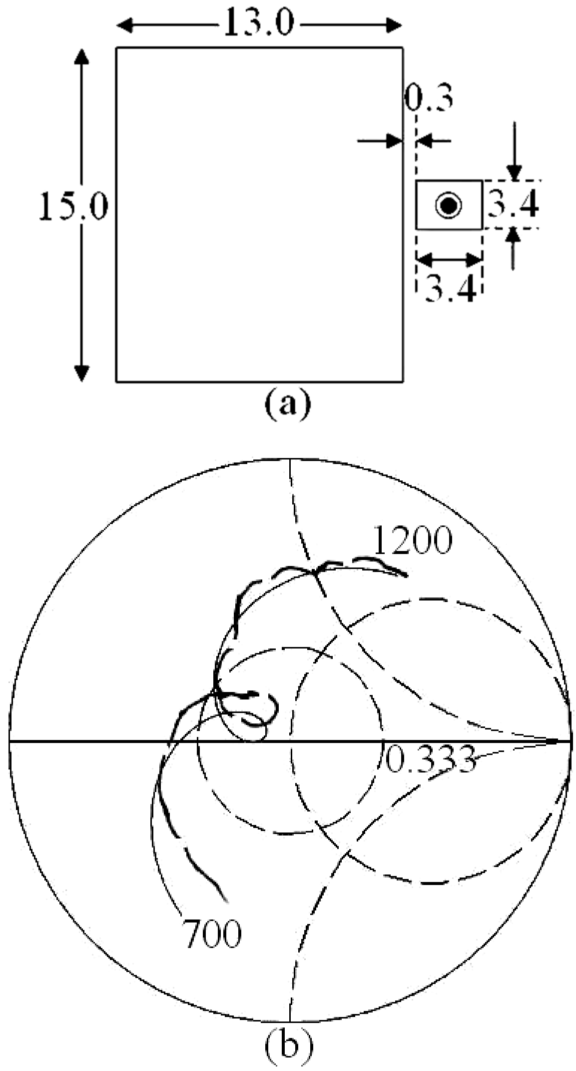

Fig 3: (a) Optimized proximity fed RMSA and its (b) input impedance loci, (——) simulated, (– – –) measured

The simulated BW is 190 MHz (20%). The measurement was carried out to validate the simulated results and the measured BW is 195 MHz (20.6%) as shown in Figure 3(b). The radiation pattern at the center frequency and over the BW is in the broadside direction with cross-polarization levels less than 15 dB as compared to that of the co-polar levels. The antenna shows peak gain of more than 7 dBi.

3. PAIR OF RECTANGULAR SLOT CUT PROXIMITY FED BROADBAND RMSA

The broadband pair of rectangular slots cut RMSA is shown in Figure 4. The pair of rectangular slots is cut along the length of RMSA as well as the pair of rectangular slot were cut on the non-radiating edges of the RMSA.

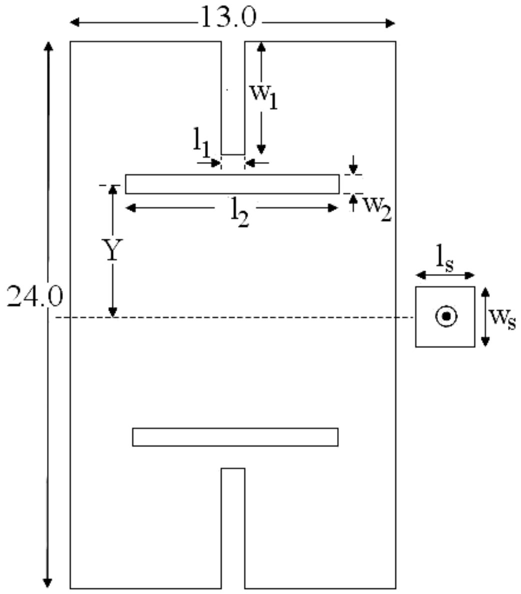

Fig 4: Broadband proximity fed pair of rectangular slots cut RMSA

The length of equivalent RMSA is selected such that it operates at around 900 MHz in its TM_{10} mode. To realize higher gain, a larger width to length ratio is selected. The RMSA dimensions are L = 13.0 cm and W = 24.0 cm which gives W/L = 1.84. The resonance curve plot for the proximity fed RMSA is shown in Figure 5

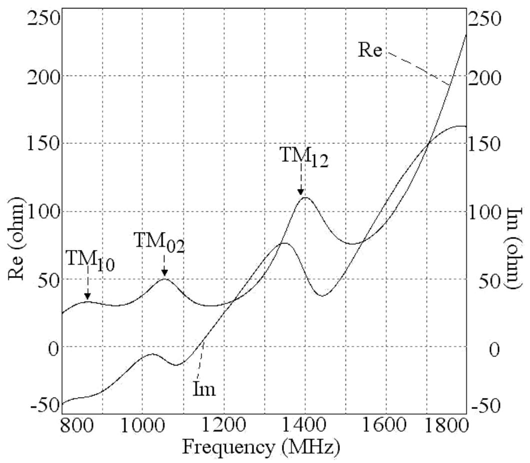

Fig 5: Resonance curve plot for equivalent RMSA

The resonance curve shows three peaks due to TM_{10}, TM_{02} and TM_{12} modes as shown in their surface current and voltage distributions in Figure 6(a – c). At TM_{10} mode the surface current shows one half wavelength variations along patch length. At TM_{02} mode the currents shows two half wave length variation along patch width. At TM_{12} mode the current shows one half wave length variation along patch length and two half wavelength variations along patch width.

Inside this RMSA first the pair of horizontal slots (l_2, w_2) were cut along the patch length. The slot length is orthogonal to the surface currents at TM_{02} mode and hence its frequency reduces. The pair of vertical slots (l_1, w_1) was cut on each of the non-radiating edges of the RMSA. These slots are orthogonal to the surface currents along the edge at TM_{12} mode and it reduces its frequency. Thus by optimizing the two pairs of rectangular slot dimensions, the two loops due to the TM_{02} and TM_{12} modes were optimized inside the VSWR = 2 circle and the optimized antenna response is shown in Figure 7. The fabricated prototype of the antenna is shown in Figure 8.

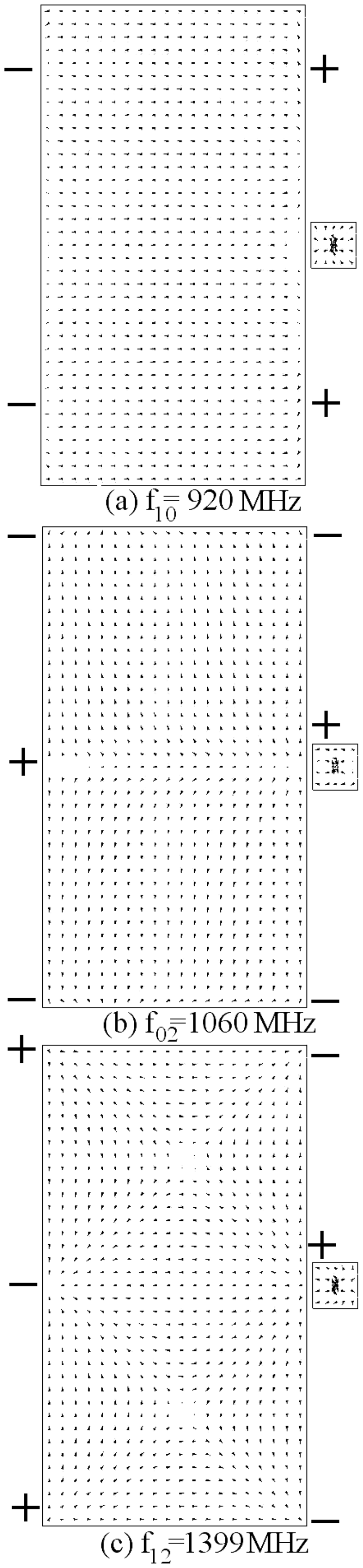

Fig 6: (a – c) Surface current and voltage distribution for equivalent RMSA at different modes

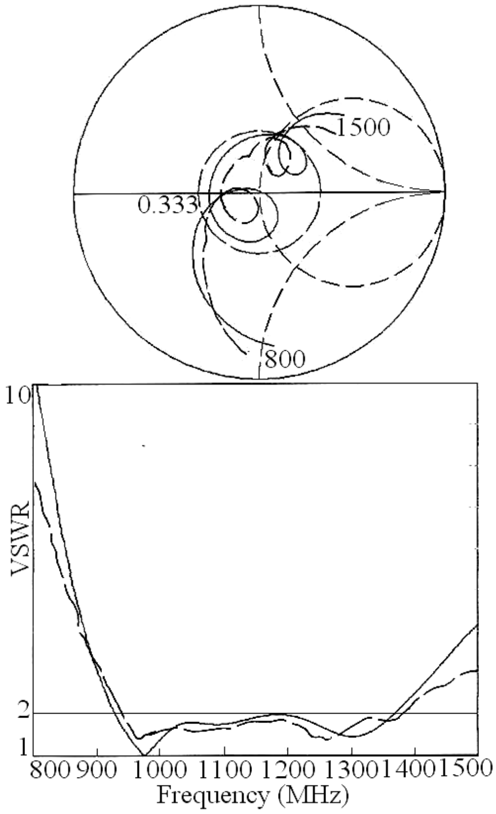

Fig 7: Input impedance and VSWR plots for pairs of rectangular slot cut RMSA

The simulated BW is 440 MHz (38%). The antenna response is experimentally verified and the measured BW is 446 MHz (38.4%). The radiation pattern over the BW is measured and is shown in Figure 9(a – c). The surface current at TM_{02} modes are varying along the patch width whereas at TM_{12} mode they are varying along patch length as well as the width. Hence the radiation pattern at TM_{02} and TM_{12} modes is in the conical direction and it shows maximum radiation in the end-fire direction. The each pair of rectangular slots modifies the directions of surface currents at TM_{02} and TM_{12} modes and they are aligned along the horizontal direction inside the patch length. Therefore the radiation pattern over the BW is in the broadside direction. However at the lower frequencies of BW a larger component of surface currents are present along the patch width and hence at those frequencies a larger cross polar radiation is observed.

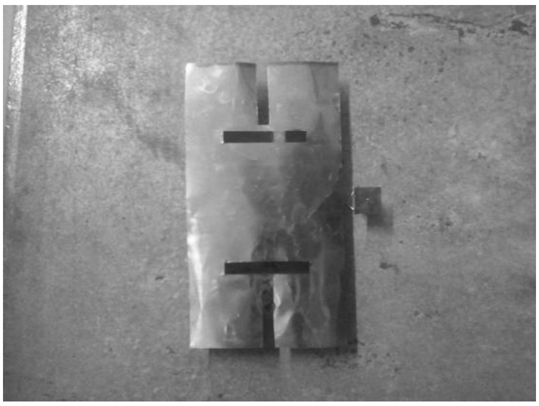

Fig 8: Fabricated prototype of pairs of rectangular slot cut RMSA

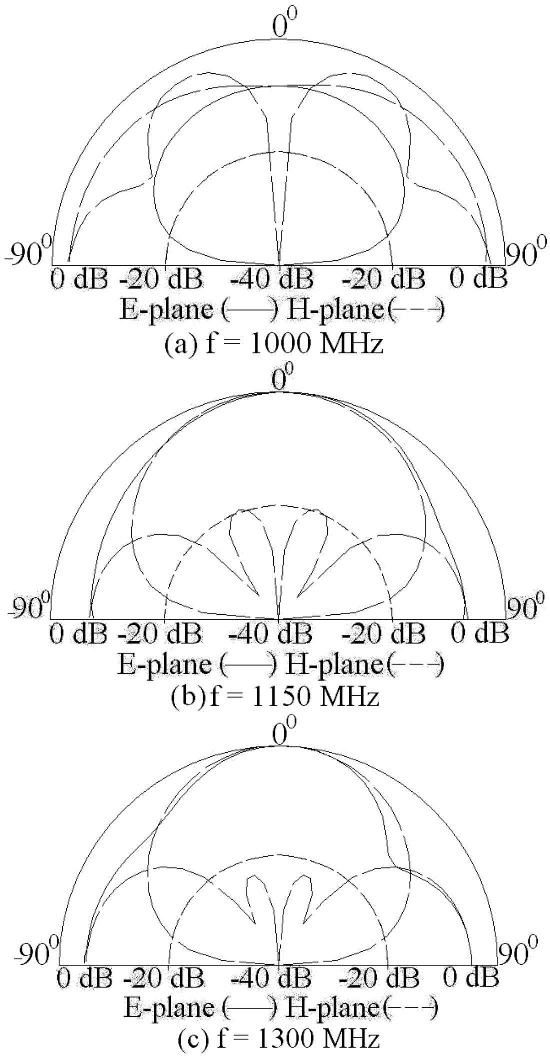

Fig 9: (a – c) Radiation pattern over BW for pairs of rectangular slot cut RMSA

The E and H-planes are aligned along $\Phi = 0^0$ and 90^0, respectively. The antenna gain over the BW is shown in Figure 10. The antenna shows a gain of more than 7 dBi over the BW with peak gain of more than 8 dBi.

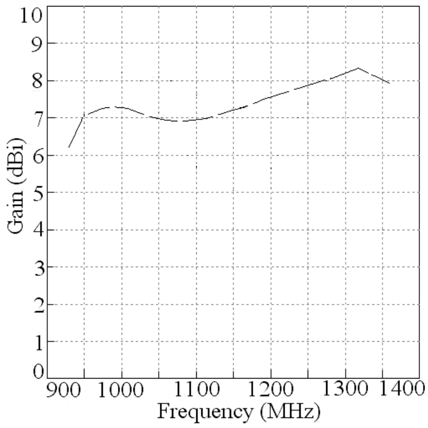

Fig 10: Gain variation over the BW for pair pairs of rectangular slot cut RMSA

4. CONCLUSIONS

The proximity fed RMSA is discussed. The proximity feeding technique increases the antenna BW for substrate thickness greater than $0.06\lambda_0$. The broadband pairs of rectangular slot cut RMSA is proposed. The slot modifies the resonance frequencies of TM_{02} and TM_{12} modes and realizes broadband response. A BW of more than 430 MHz at round 1100 MHz is obtained. Although the broadband response is due to the orthogonal modes, these pair of rectangular slots modifies the directions of surface currents at TM_{02} and TM_{12} modes and they are aligned along the patch length. Therefore the radiation pattern is in the broadside direction with E and H-planes aligned along $\Phi = 0^0$ and 90^0, respectively. The antenna has a gain of more than 8 dBi. Thus due to the above antenna characteristics like gain, BW and radiation pattern the proposed antenna finds an application in mobile communication environment.

5. REFERENCES

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