INTERNATIONAL JOURNAL OF MICROWAVE AND OPTICAL TECHNOLOGY,

VOL.2 , NO.3 , JULY 2007

Half U-Slot Loaded Multi-Band Rectangular Microstrip Antennas

Amit A. Deshmukh[1] and K. P. Ray[2]

1. Telecom., MPSTME, NMIMS (DU), Vile-Parle (W), Mumbai – 400 056, India
2. RFMS, SAMEER, IIT Campus, Powai, Mumbai – 400 076, India
Tel.: 91 22 2618 3688, Fax: 91 22 2611 4512, Email: amitdeshmukh76@yahoo.com, kpray@rediffmail.com

Abstract: Multi-band microstrip antenna is realized by cutting a quarter wavelength or half wavelength slots inside the patch. In this paper, dual and triple band rectangular microstrip antennas, by cutting a quarter wavelength half U-slots inside the patch are proposed. The multi-port network models for these multi-band antennas are also proposed which gives the voltage distributions at all the frequencies. A good agreement between the simulated, multi-port network model and measured results is obtained.

***Index terms*: multi-band microstrip antenna, Half U-slot, multi-port network model**

I. INTRODUCTION

The compact microstrip antenna (MSA) is realized by cutting the slot inside the patch which lengthens its surface current length [1]. When these slots are cut at an appropriate position inside the patch, and when they are of nearly half or quarter wave in length, a resonant mode near the patch resonance is introduced and yields the multi-band MSA [1 – 3]. For these multi-band MSAs the same polarization at all the frequencies is realized when patch and slot modes are in the same direction and the dual polarization when these modes are orthogonal to each other. The broadband RMSA using compact half U-slot cut on one of its non-radiating edge is reported [4]. In this paper, half U-slot is used to realize the multiple frequencies in the same rectangular MSA (RMSA). The dual and triple band response is realized by cutting half U-slots.

The multi-port network model (MNM) is very efficient and simpler method to analyze MSA and it gives close match with measured data for the substrate thickness less than $0.04\lambda_0$ [5]. In MNM, the fields inside and outside the patch are modeled separately. Inside the patch they are modeled using the Green's Function of the patch geometry and outside the patch they are modeled using radiation and surface wave conductance which accounts for radiation from the patch and the surface waves. The surface wave conductance can be ignored for smaller substrate thickness. The patch edges are divided into number of ports which have finite port widths. The number of ports along any particular edge is decided as per the field variation along that edge. Further, using the segmentation method, the input impedance of the patch is calculated. Using the impedance matrix generated in the MN model, the voltage distribution along the edges of the patch is calculated and from which the radiation pattern is obtained. The voltage distribution is a very unique feature of MNM as the understanding of the resonant mode at a given frequency is more explanatory as compared to that of the current distribution generated using other methods.

In this paper, to get an insight into the mode distributions at various multi-band frequencies, these multi-band RMSAs are analyzed using their MN models. These RMSAs are first simulated using IE3D software [6] on glass epoxy substrate ($\varepsilon_r = 4.3$, h = 0.16 cm, and tan $\delta = 0.02$) followed by MN modeling and experimental verification.

II. DUAL BAND RMSA

A half U-slot cut dual band RMSA is shown in Fig. 1(a). The resonant frequency of the un-slotted RMSA is around 880 MHz. The half U-slot length nearly equals quarter wave length at the required dual frequency and it is cut on one non-radiating edge of the RMSA. This ensures the same polarizations for the slot and patch modes (TM_{10}). The increase in vertical length of the slot increases the impedance for the patch mode and reduces its resonance frequency. The feed point is placed along the center of the width to ensure radiation pattern with lower cross-polarization levels. For the optimized dual band RMSA, the simulated dual frequencies and bandwidth (BW) are 794 and 1091 MHz and 11 and 16 MHz, respectively as shown in Fig. 1(c).

The MN model for this dual band RMSA is shown in Fig. 1(b). The MSA is divided into four segments and as slot width is smaller, larger number of ports is taken along the segmented edges to care for large field variation. The input impedance and VSWR plots calculated using segmentation method are shown in Fig. 1(c). The dual frequencies and BWs are 796 and 1110 MHz and 13 and 17 MHz, respectively, which agrees well with simulated results. The voltage distributions using MNM is shown in Fig. 2(a, b). At first frequency (f_1) patch mode is dominant as half wavelength variation is present along non-radiating edges of the patch. At second frequency (f_2), slot mode is dominant as quarter wavelength variation is noticed along inner half U-slot length. As the width of the patch inside the half U-slot is smaller, a higher impedance variation is present inside the slot.

III. TRIPLE BAND RMSA

For the triple band response an additional half U-slot is cut on the other non-radiating edge of above dual band RMSA as shown in Fig. 3(a). The dimensions of second half U-slot are chosen such that three different resonant frequencies are realized. For the required triple frequencies, the triple band response is optimized by varying slot dimensions and the feed point location. Here, the RMSA is optimized for triple band operation at 618, 752 and 1145 MHz and with the BW of 11, 9 and 23 MHz, respectively and its simulated input impedance and VSWR plots are shown in Fig. 3(c). For any other frequencies, the optimization of the two half U-slot lengths followed by the feed point location gives the required tunable tri-band operation.

The triple band RMSA is analyzed using its MN model as shown in Fig. 3(b). As the MSA is complex in shape, in the MN model it is divided into seven segments. Using MNM and the segmentation method, the frequencies and BWs are 606, 753 and 1164 MHz and 12, 8 and 22 MHz, respectively as shown in Fig. 3(c). The triple frequency response is experimentally verified and the picture of the fabricated antenna is shown in Fig. 4(a). The experiment was carried out using Hewlett Packard Network analyzer having frequency range of up till 10 GHz. The measured frequencies and BWs are 644, 781 and 1184 MHz and 9, 10 and 21 MHz, respectively as shown in Fig. 4(b). These measured results are in good agreement with simulated and MNM results.

The voltage distributions at the three frequencies are shown in Fig. 5(a – c). The f_1 is governed by patch (TM_{10}) mode. However the distribution is not exactly similar to that of the TM_{10} mode, which is due to the presence of resonant slots along the patch edges. The presence of two half U-slot further reduces the patch frequency as compared to the dual band MSA. The f_2 is governed by the half U-slot with longer horizontal length and f_3 is governed by half U-slot with smaller horizontal length. A quarter wavelength variations are noticed along their inner slot lengths at their respective frequencies. The radiation pattern at the three frequencies as shown in Fig. 6(a – c) is in the broadside directions with E and H-planes aligned along $\Phi = 0^0$ and 90^0, respectively. The cross polarization level is higher at f_2, due to the asymmetrical voltage distribution along the slotted patch.

These patches were fabricated on glass epoxy substrate hence they have lower gain. The gain can be increased by using their suspended configurations. The BW can be increased by using their multi-resonator gap-coupled configurations.

IV. CONCLUSIONS

The dual and triple band half U-slot cut RMSAs are proposed. Also their MN models are proposed. The voltage distribution using MN model helps to analyze mode distribution for these multi-band MSAs. The results obtained using simulation, MNM and measurements are in good agreement with each other.

V. REFERENCES

[1] G. Kumar and K. P. Ray, ‘Broadband Microstrip Antennas’, Artech House, USA, 2003

[2] K. L. Wong, ‘Compact and Broadband Microstrip Antennas’ (John Wiley and Sons, Inc., New York, 2002)

[3] K.L. Wong, J. H. Lu, “Slot-loaded, meandered rectangular microstrip antenna with compact dual frequency operation”, vol. 34, pp. 1048 – 1050, 28th May 1998

[4] A. A. Deshmukh, and G. Kumar, ‘Compact Broadband U-slot loaded Rectangular Microstrip Antennas’, Microwave & Opti. Tech. Letters, 2005, 46, 6, 556 – 559

[5] James, J. R., and Hall, P. S.: Handbook of microstrip antennas, Vol. I & II, (Peter Peregrines Ltd. 1989)

[6] IE3D 9.1, Zeland Software Inc., Fremont, CA, USA, 2000

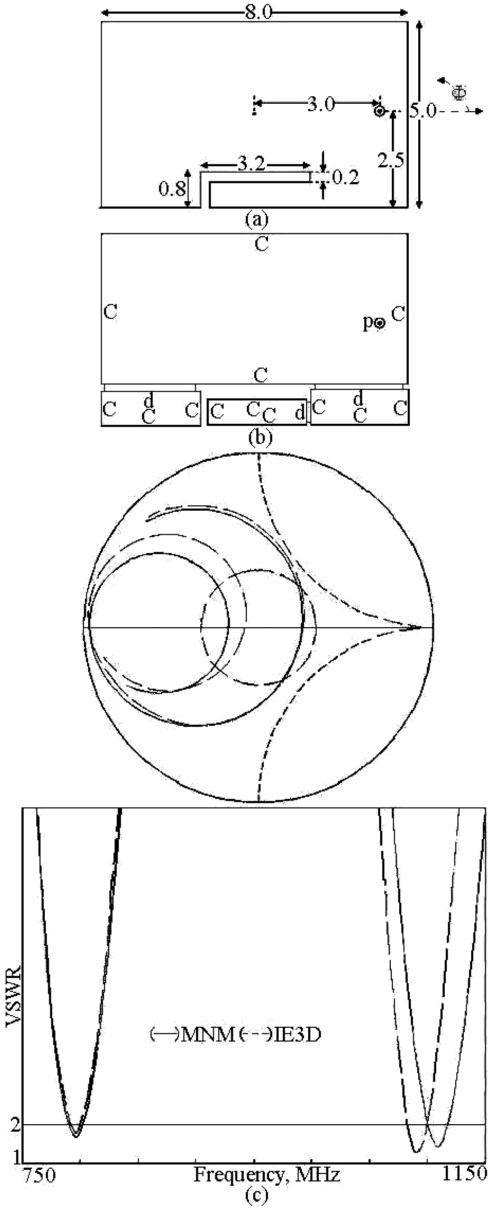


Figure 1: (a) Dual band RMSA, its (b) MN model, its (c) input impedance and VSWR plots

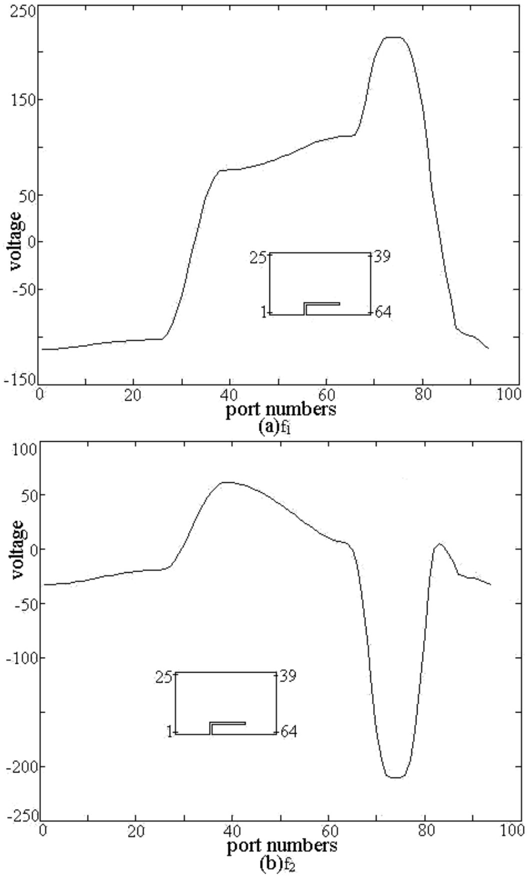


Figure 2: Voltage distribution at dual frequencies for Dual band RMSA at (a) 796 MHz (b) 1110 MHz

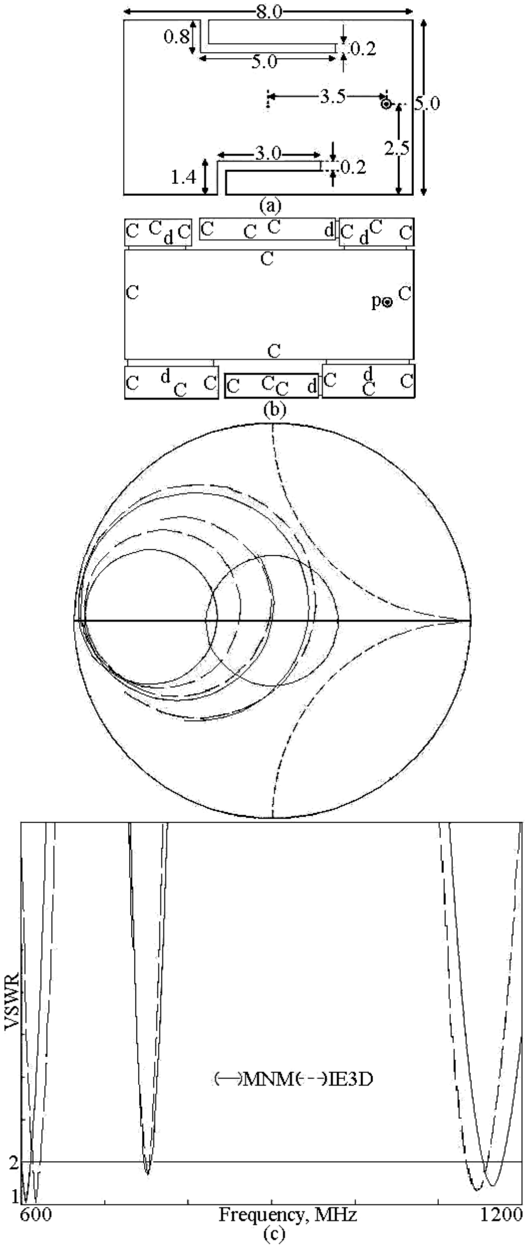
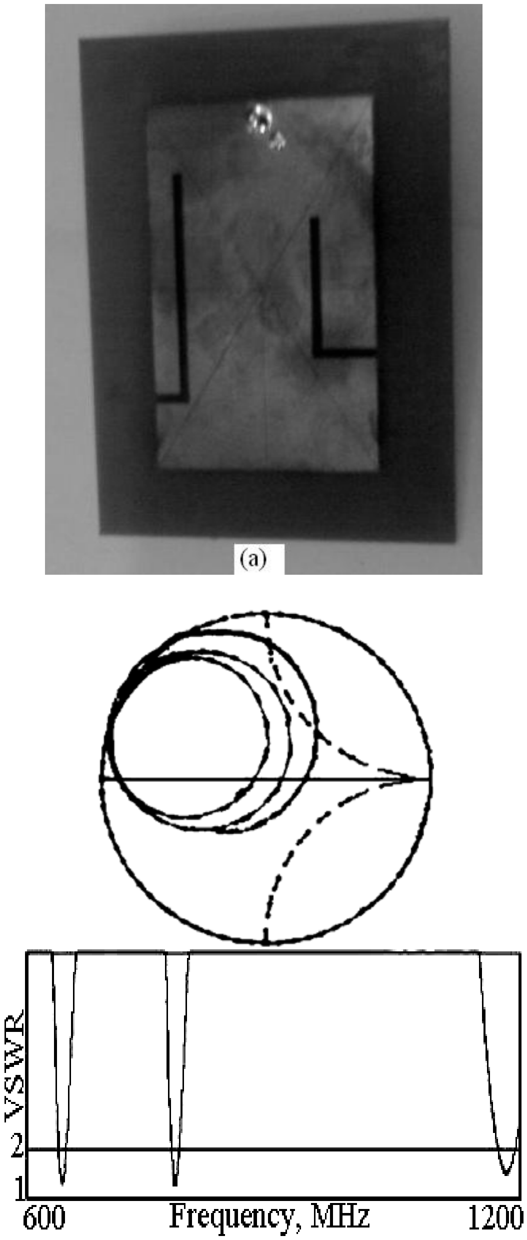


Figure 3: (a) Triple band RMSA, its (b) MN model and its (c) input impedance and VSWR plots



(b)

Figure 4: (a) picture of triple band RMSA and its (b) measured input impedance and VSWR plots

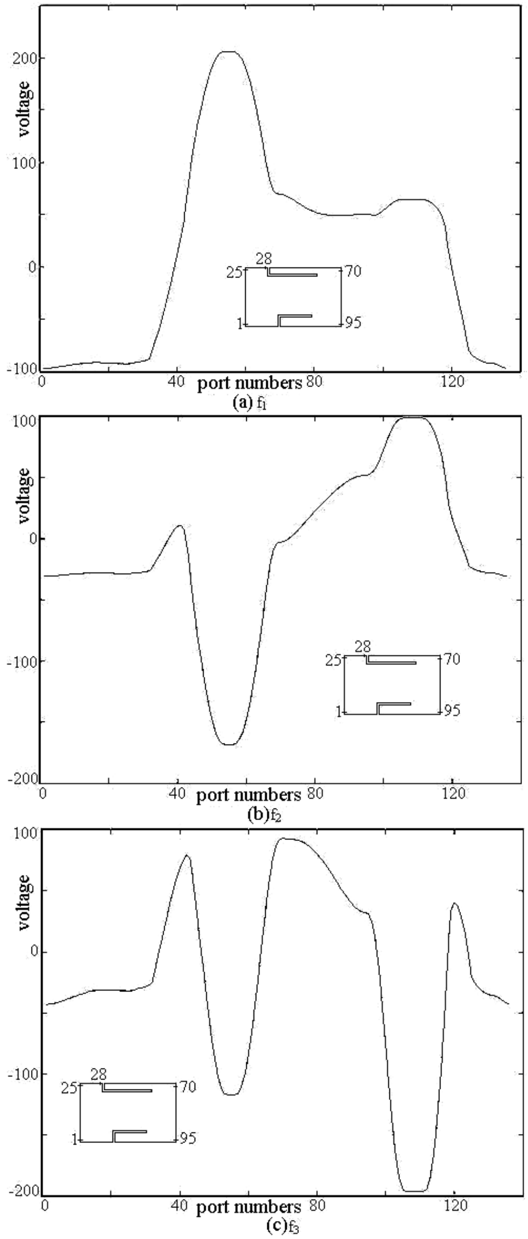


Figure 5: Voltage distributions for triple band RMSA at (a) 606 MHz (b) 753 MHz and (c) 1164 MHz

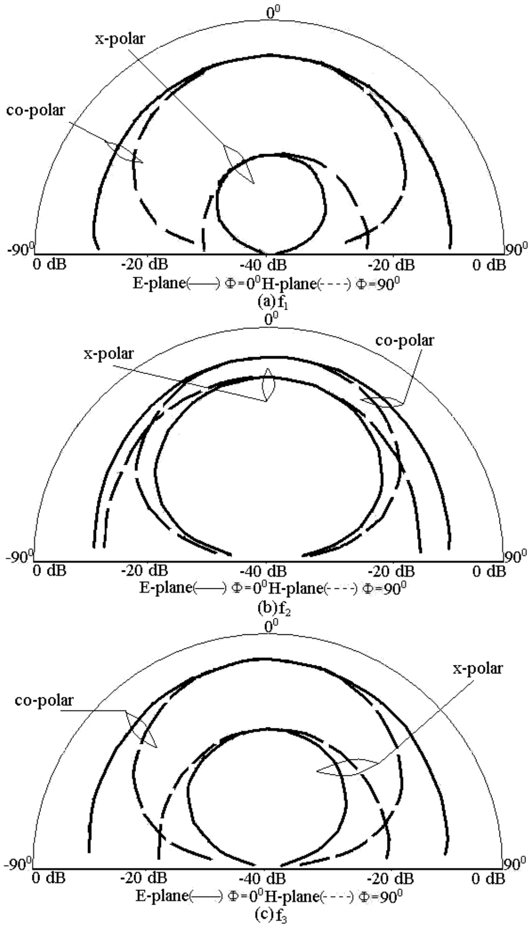


Figure 6: (a – c) Radiation patterns for triple band RMSA