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Single layer modified rectangular microstrip array antenna for multi band and wide band applications

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A four-element modified rectangular microstrip array antenna (4MRMSAA) is designed and further extended to eight element modified rectangular microstrip array antenna (8MRMSAA). A comparative study is made between the proposed antennas. The experimental results show that 4MRMSAA operates for multi band and 8MRMSAA operates for wide band with an improvement (39.34%) in impedance bandwidth. This improvement in the impedance bandwidth of 8MRMSAA is 13.80 times more as compared to single rectangular radiating element (RMSA). The experimental results of the proposed antennas have been presented in terms of impedance bandwidth, return loss, gain, half power beam width (HPBW) and cross polarization levels. These multi band and wide band antennas have applications in modern communications and radar communication systems.

Keywords: Modified rectangular microstrip array antenna (MRMSAA), Multi band antenna, Wide band antenna, Corporate feed

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1 Introduction

Microstrip antennas are increasingly finding applications in microwave communication systems as they are light weight, have planar configuration and inexpensive to fabricate. The most serious limitation is the narrower impedance bandwidth that resonates at a single frequency. Various techniques are available for broadening the impedance bandwidth[1-6].

A slot antenna is of major importance because of its simple structure. When a microstrip slot antenna is fed using a microstrip line it does not add weight and size to the system. Slot loaded patch antennas have attracted much attention in recent years due to their capability of realizing various functionalities. For example, a square patch antenna with a slot along the diagonal direction can realize circular polarization with a single feed[7]. Slots are also used to tune the resonant frequencies of antennas[8]. Antenna size can be reduced by properly incorporating slots to make the electric current path mender[9]. U-slot patch antennas[10,11] and E-shaped patch antennas[12] have recently been proposed to achieve a wide bandwidth with the help of slots.

As the slot loading technique is simple and effective in enhancing the impedance bandwidth of microstrip antennas compared to other techniques available in the literature, an effort is made to enhance the impedance bandwidth of rectangular microstrip array antenna by using slot loading technique.

In this proposed study, a four element rectangular microstrip array antenna (4RMSAA) (ref. 13) is modified to plus shape array by embedding wide slots at the edges of each element[14-18], which results in the improvement of antenna parameters. These slots are considered as wide slots as their width is comparable to their length. The wide slot is selected because it is more effective in enhancing the impedance bandwidth than the narrow slot. Further, the study is carried out for eight element array antenna.

S N Mulgi *et al.*[19,20] in the year 2008 and 2009 proposed the wide band gap-coupled slot rectangular array and aperture coupled equilateral triangular array, respectively. In both the cases, they have used the aperture coupling technique, gap-coupling technique and slot loading technique. They have achieved the impedance bandwidth of 26.72 and 19.07%, respectively. The gain in both the cases was found to be negative (-10.38 and -7.37 dB). But the proposed antenna uses single layer and achieved better results both in terms of impedance bandwidth and gain. In 2005, Chakraborthy *et al.*[21] have presented 4x4 rectangular aperture coupled microstrip array antenna and achieved nearly 11% of impedance bandwidth. Here, also the proposed antennas are good. Pushpanjali *et al.*[22], in 2008, presented a equilateral triangular microstrip array antenna for broadband operations. In the study, authors have used aperture coupling and slot loading technique for four element linear array that achieved dual band with impedance bandwidth of 3.89 and 19.85%, respectively. The proposed work is better as only single layer has been used and good results are achieved. Konda *et al.*[23,24] in 2007 and 2008, reported slot loaded gap coupled microstrip array antenna for wide impedance bandwidth and aperture fed slot loaded gap coupled microstrip array antenna for wideband operation and in both the studies, aperture coupling, gap coupling and slot loading technique has been used and impedance bandwidth of 34.17 and 35.81% have been achieved for four and eight element array, respectively. In the present study, 8MRMSAA has shown 39.34% of impedance bandwidth by using only single layer and slot loading technique. The impedance bandwidth is 1.099 times more as compared to the study of Konda *et al.*[24]

2 Antenna configurations

The proposed antennas are designed using low cost glass epoxy substrate material having dielectric constant ε_r=4.2, and thickness h=0.16 cm. The geometry of 4MRMSAA is shown in Fig. 1. The elements of array are designed for 9.4 GHz frequency with dimensions (L=0.66 and W=0.98 cm). A rectangular wide slot of dimensions (L_S=0.33 and W_S=0.22 cm) is placed at each edge of elements which results into plus shape. The dimensions of wide slots are taken in terms of λ_0, where, λ_0, is the free space wavelength in cm. The length (L_g=4.27 cm) and width (W_g = 12.76 cm) of the ground plane of antenna is calculated using L_g = 6h + L and W_g = 6h + W (ref. 25). The elements of this array antenna are excited through simple corporate feed arrangement. This feed arrangement consist of matching transformer, quarter wave transformer, coupler and power divider for better impedance matching between feed and radiating elements[26]. A two-way power divider made up of 70Ω matching transformer of dimension (L_{70} = 0.41, W_{70} = 0.16 cm) is used between 100Ω microstrip line of dimension (L_{100} =0.83, W_{100} = 0.07 cm) and 50Ω microstrip line of dimension (L_{50} = 0.41, W_{50} = 0.32 cm). A coupler of dimension (C_L = C_W = 0.32 cm) is used between 50Ω microstrip lines to couple the power[27,28]. The 50Ω microstrip line is connected at the center of the driven element through a quarter wave transformer of dimension (L_t = 0.42, W_t = 0.05 cm) for better impedance matching. At the tip of microstrip line feed of 50Ω, a coaxial SMA connector is used for feeding the microwave power. The array elements are kept at a distance (D = 2.79 cm) from their center point. This optimized distance is selected in order to add the radiated power in free space[29]. Further, it is extended to 8MRMSAA. The photograph of the fabricated 4MRMSAA and 8MRMSAA is shown in Fig. 2.

3 Experimental results and discussion

The impedance bandwidths over return loss less than –10 dB for the proposed antennas are measured. The measurements are taken on Vector Network Analyzer (Rohde & Schwarz, German make ZVK Model No. 1127.8651). The variation of return loss versus frequency of RMSA, 4MRMSAA and

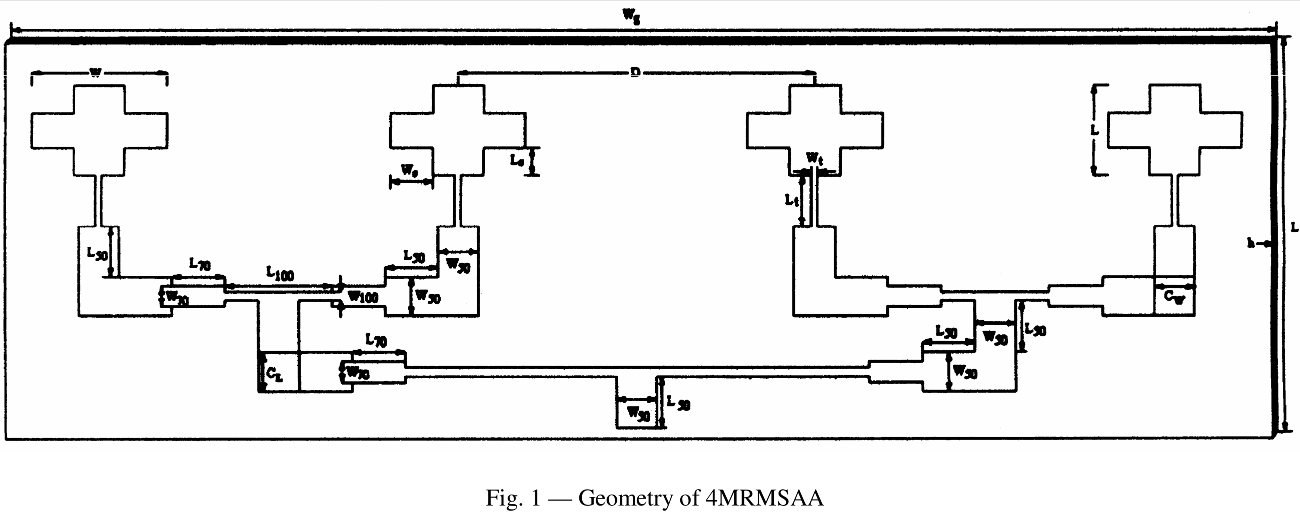

Fig. 1 — Geometry of 4MRMSAA

8MRMSAA is shown in Fig. 3. It is observed from the figure that 4MRMSAA offers multi band at 6.69, 8.09, 10.82, 12.68 and 14.36 GHz with a magnitude of 280 (4.18%), 250 (3.09%), 810 (7.60%), 770 (6.04%) and 580 MHz (3.9%), respectively. The improvement in the individual bands as compared to RMSA (2.85%) is due to slots resonating nearer to the fundamental resonance of radiating elements causing enhancement in the impedance bandwidth. When compared to 4RMSAA (ref. 13), the proposed antenna is resonating for more bands with improvement in impedance bandwidth. The minimum return loss measured at each individual band is presented in Table 1. From the table, it is clear that the return loss of 4MRMSAA is also improved as compared to 4RMSAA (ref. 13).

Further, from the graph, it is clear that 8MRMSAA is resonating for two bands at 7.36 and other a wide band with multi-resonance at 7.99, 8.72, 9.35 and 11.07 GHz. The impedance bandwidth of first band resonating at 7.36 GHz is found to be 280 MHz (3.15%). The impedance bandwidth of second band which is resonating from 7.78 GHz to 11.59 GHz is found to be 39.34% which is 13.80 times more as compared to RMSA and 1.50 times more as compared to 8RMSAA (ref. 13). This improvement in impedance bandwidth is due to combined and closer resonance of all the eight elements fed by corporate feed network and the slots where all the elements resonate at their fundamental resonance and the slots resonate closer to it, which results into an improvement in the impedance bandwidth. The minimum return loss at each resonance is measured and is presented in Table 1. From the table, it is clear that return loss of 8MRMSAA is also improved as compared to 8RMSAA (ref. 13).

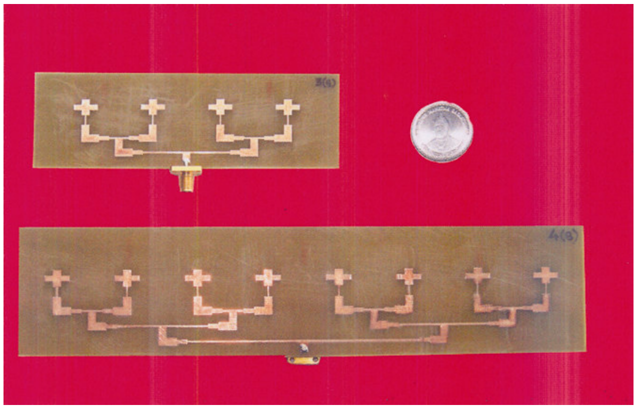

Fig. 2 — Photograph of fabricated 4MRMSAA and 8MRMSAA

The X-Y plane co-polar and cross-polar radiation patterns of 4MRMSAA and 8MRMSAA are measured at their resonating frequencies and are shown in Figs (4-5). These figures indicate that both the antennas show broad side radiation characteristics. The side lobe levels and cross polarization levels of these antennas at the resonating frequencies is

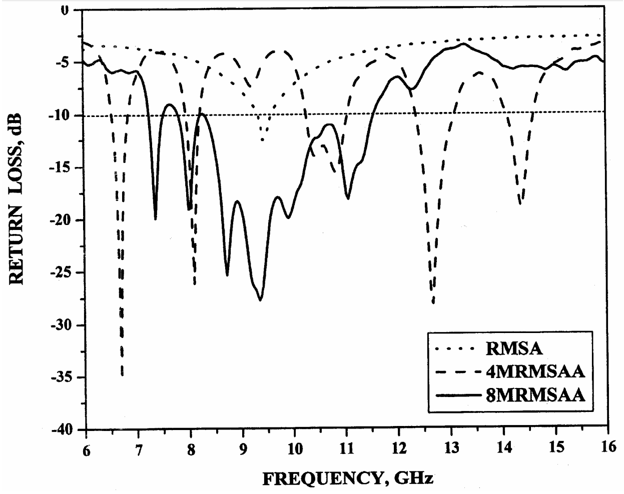

Fig. 3 — Variation of return loss *vs* frequency of RMSA, 4MRMSAA and 8MRMSAA

Table 1 — Measured return loss, side lobe level, X-polar level, gain and calculated HPBW with respect to resonating frequencies

Antenna	Frequency, GHz	Minimum return loss, dB	Side lobe level, dB	X-polarization level, dB	Gain, dB	HPBW
4MRMSAA	6.69	-35.28	-4	-20	4.3	24^0
	8.09	-26.17	----	-14	----	Split beam
	10.82	-15.64	-17	-20	10.5	15^0
	12.68	-28.18	----	-16	----	Split beam
	14.36	-19.05	-4	-18	8.3	20^0
8MRMSAA	7.36	-19.93	----	-15	----	Split beam
	7.99	-26.71	-12	-13	----	Split beam
	8.72	-25.29	-7	-17	9.52	12^0
	9.35	-27.75	-5	-15	8.41	3^0
	9.95	-23.58	-4	-15	3.7	13^0
	11.07	-19.78	-7	-18	5.4	14^0

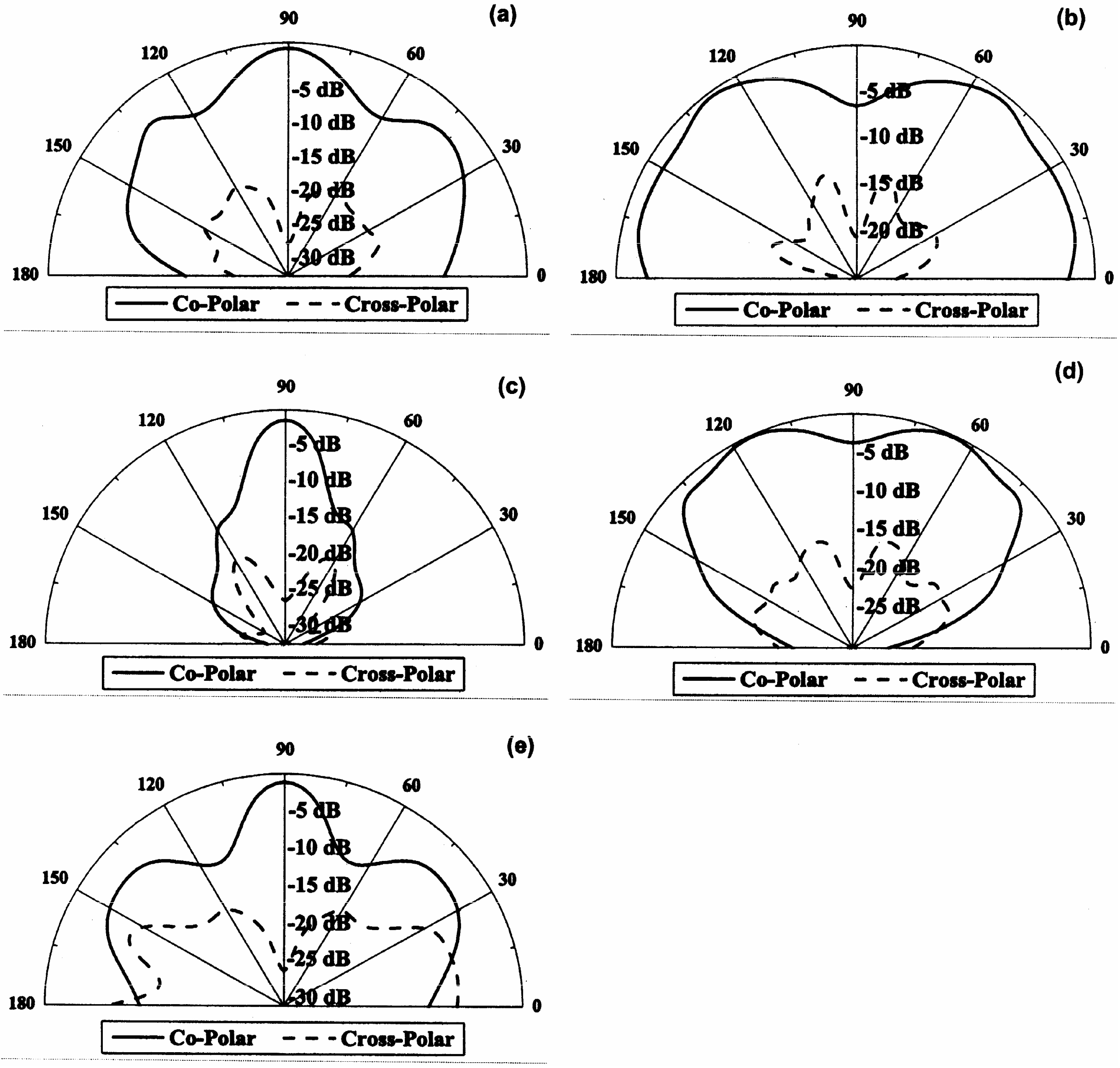

Fig. 4 — Variation of relative power *vs* azimuth angle of 4MRMSAA at: (a) 6.69 GHz; (b) 8.09 GHz; (c) 10.82 GHz; (d) 12.68 GHz; and (e) 14.36 GHz

measured and are shown in Table 1 for the sake of comparison. When compared (ref. 13), both side lobe levels and cross polarization levels are also improved. Figures 4 (b and d) show the radiation patterns of 4MRMSAA measured at 8.09 and 12.68 GHz, respectively. At these frequencies, antenna shows split beam radiation patterns which are useful in SAR for generating a pair of forward and backward squinted beams and provide simultaneous measurement of both the along-track and the cross-track velocities[30]. Figures 5 (a-b) show the radiation pattern of 8MRMSAA measured at 7.36 and 7.99 GHz. At these frequencies, 8MRMSAA shows the split beam character as of 4MRMSAA and it can also be used in SAR.

The half power beam width (HPBW) of 4MRMSAA and 8MRMSAA is calculated for their resonating frequencies and is presented in Table 1 for the sake of comparison.

The gain of antennas is measured at the resonating frequencies and as shown in Table 1 indicates that the gain of both the antennas is improved when compared to earlier work[13]. This shows that the use of slots and array configuration also improves the antenna gain considerably[31].

As 8MRMSAA gives improved impedance bandwidth, the variation of input impedance profile and phase plot is shown in Figs 6 and 7, respectively. It is seen that the input impedance has multiple loops at the center of Smith chart that validates its wide-band and multi resonance operation.

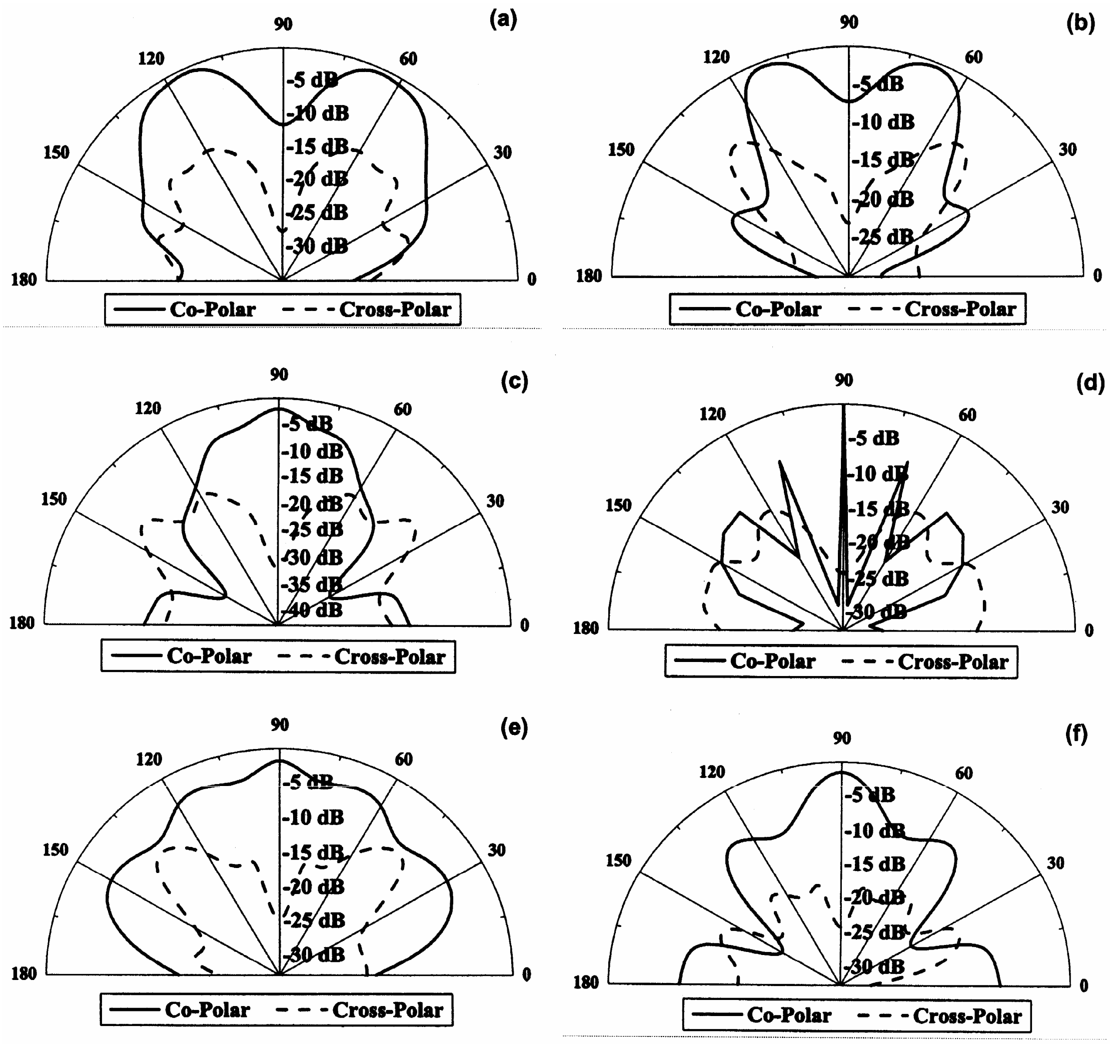

Fig. 5 — Variation of relative power *vs* azimuth angle of 8MRMSAA at: (a) 7.36 GHz; (b) 7.99 GHz; (c) 8.72 GHz; (d) 9.35 GHz; (e) 9.95 GHz; and (f) 11.07 GHz

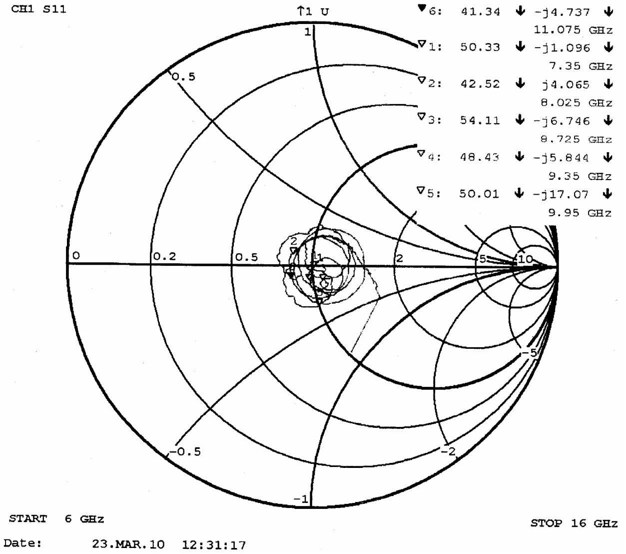

Fig. 6 — Input impedance profile of 8MRMSAA

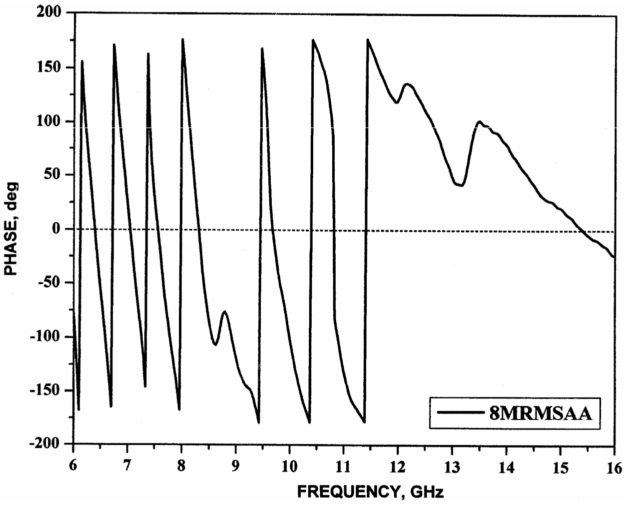

Fig. 7 — Phase plot of 8MRMSAA

4 Conclusions

The detailed experimental study shows that the antennas are quite simple in design and fabrication and quite good in enhancing the impedance bandwidth and give better gain with broadside radiation pattern at the resonating frequencies. The multi-band microstrip patch array antenna may provide an alternative to large bandwidth planar antennas in applications in which large bandwidths are needed for operating at two separate transmit-receiver bands. When the two operating frequencies are far apart, a multi-band patch array structure can be conceived to avoid the use of separate antennas. These antennas are also superior as they use low cost substrate material and find applications in modern communication system, microwave wireless communication system and in radar communication systems.

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References

1 Pozar D M, Microstrip antenna aperture-coupled to a micro stripline, *Electron Lett (UK)*, 21 (1985) 49.

2 Song Quing & Zhang Xue-Xia, A study on wide band gap-coupled microstrip antenna array, *IEEE Trans Antennas Propag* (USA)*,* 43 (1995) 313.

3 Latif Saced I, Shafai Lotfollah & Sharma Satish Kumar, Bandwidth enhancement and size reduction of microstrip slot antennas, *IEEE Trans Antennas Propag* (USA)*,* 53 (2005) 994.

4 Meshram M K & Vishvakarma B R, Gap-coupled microstrip array antenna for wide-band operation, *Int J Electron (UK)*, 88 (2001) 1161.

5 Wood C, Improved bandwidth of microstrip antennas using parasitic elements, *IEE Proc Microw Antennas Propag (UK),* 127 (1980) 231.

6 Kumar G & Gupta K C, Non-radiating edge and four edges gap coupled multiple resonator broad band microstrip antennas, *IEEE Trans Antennas Propag (USA),* 35 (1985) 173.

7 Sharma P C & Gupta K C, Analysis and optimized design of single feed circularly polarized microstrip antennas, *IEEE Trans Antennas Propag (USA),* 31 (1983) 949.

8 Maci S, Gentili G B & Avitaoile G, Single-layer dual frequency patch antenna, *Electron Lett (UK),* 29 (1993) 1441.

9 Dey S & Mittra R, Compact microstrip antenna, *Microw Opt Technol Lett (USA),* 12 (1996) 12.

10 Lee K F, Luk K M, Tong K F, Shum S M, Hunyh T & Lee R Q, Experimental and simulated studies of coaxial fed U-slot rectangular patch antenna, *IEE Proc Microw Antennas Propag (UK),* 144 (1997) 354.

11 Weigand S, Haff G H, Pan K H & Bernhard J T, Analysis and design of broad band single layer rectangular U-slot microstrip patch antennas, *IEEE Trans Antennas Propag (USA),* 49 (2001) 1094.

12 Yang F, Zang X X, Xiaoning Ye & Rahmat Y S, Wideband E-shaped patch antennas for wireless communications, *IEEE Trans Antennas Propag (USA),* 49 (2001) 1094.

13 Mallikarjun S L, Madhuri R G, Malipatil S A & Hadalgi P M, Development of microstrip array antennas for wide band and multi band applications, *Indian J Radio Space Phys,* 38 (2009) 289.

14 Mallikarjun S L, Konda R B, Mulgi S N, Satnoor S K & Hunagund P V, Design and development of a wide band high gain microstrip patch antenna, *ICFAI Univ J Sci Technol (India),* 4 (2008) 23.

15 Mallikarjun S L, Madhuri R G, Malipatil S A & Hadalgi P M, Compact high gain multi frequency antenna, *IEEE International Symposium on Microwaves 2008* (Bangalore, India)*,* 2008, 369.

16 Sze JaiYi & Wong Kin-Lu, Bandwidth enhancement of a microstrip-line-fed printed wide-slot antenna, *IEEE Trans Antennas Propag (USA),* 49 (2001) 1020.

17 Ooi B L & Ang I, Broadband semicircle-fed flower-shaped microstrip patch antenna, *Electron Lett (UK),* 41 (2005) 939.

18 Mirzapur B & Hassani H R, Wideband and small size star-shaped microstrip patch antenna, *Electron Lett (UK),* 42 (2006) 1329.

19 Mulgi S N, Konda R B, Pushpanjali G M, Satnoor S K & Hunagund P V, Design and development of wideband gap-coupled slot rectangular microstrip array antenna, *Indian J Radio Space Phys,* 37 (2008) 291.

20 Mulgi S N, Pushpanjali G M, Konda R B, Satnoor S K & Hunagund P V, Broadband aperture-coupled equilateral triangular microstrip array antenna, *Indian J Radio Space Phys,* 38 (2009) 174.

21 Chakraborty Samik, Gupta Bhaskar & Poodar D R, Development of closed form design formulae for aperture coupled microstrip antenna, *J Sci Ind Res (India)*, 64 (2005) 482.

22 Pushpanjali G M, Konda R B, Mulgi S N, Satnoor S K & Hunagund P V, Equilateral triangular microstrip array antenna for broadband operation, *Microw Opt Techol Lett (USA)* 50 (2008) 1834.

23 Konda R B, Mulgi S N, Satnoor S K & Hunagund P V, Slot-loaded gap-coupled microstrip array antenna for wide impedance bandwidth, *Microw Opt Techol Lett (USA),* 49 (2007) 3014.

24 Konda R B, Pushpanjali G M, Mulgi S N, Suryakanth B, Satnoor S K & Hunagund P V, Aperture fed slot loaded gap-coupled microstrip array antenna for wide band operation, *IEEE International Symposium on Microwaves 2008* (Bangalore, India), 2008, 64.

25 Bahl I J & Bharatia P, *Microstrip Antennas* (Artech House, New Delhi), 1981.

26 Lee Kai Fong & Weichen, *Advances in Microstrip and Printed Antennas* (John Wiley, New York), 1997.

27 Jeong Kim I I & Young Joong Yoon, Design of wideband microstrip array antenna using the coupled lines, *IEEE Antenna and Propagation Society International Symposium* (Salt Lake City, Utah), 3 (2000) 1410.

28 Qing X M & Chia Y W M, Circularly polarized circular ring slot antenna fed by stripline hybrid coupler, *Electron Lett (UK),* 35 (1999) 2154.

29 Constantine Balanies A, *Antenna Theory Analysis and Design* (John Wiley, New York), 1982.

30 Huang John & Madsen Soren N, A dual beam microstrip array antenna, *IEEE Antenna and Propagation Society International Symposium* (Chicago), 1 (1992) 147.

31 Huang John, A Ka-band circularly polarized high-gain microstrip array antenna, *IEEE Trans Antennas Propag (USA),* 43 (1995) 113.