Journal of Physics: Conference Series

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To cite this article: P A Ambresh *et al* 2013 *J. Phys.: Conf. Ser.* **435** 012022

Journal of Physics: Conference Series **435** (2013) 012022 doi:10.1088/1742-6596/435/1/012022

Planar Microstrip Slot Antenna for S & C band Wireless Applications

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Abstract. In this paper, compact planar microstrip antennas comprising of broad slots for enhancing various antenna parameters are discussed and presented. The proposed microstrip slot antennas achieved a compactness of maximum 58 % with a peak gain of 7.58 dB. These antennas can be operated for S band applications such as WiMax, operating in the frequency range of 3.3 – 3.6 GHz, RADAR, WLAN, fixed satellite services and maritime mobile services etc. covering 2 - 6 GHz frequency range. The antennas can be used as a compact antenna system where limited size is a foremost requirement. Results also show the satisfactory performance with the dual band frequency characteristics. Details of the antenna design structure, results of return loss (RL), impedance bandwidth and radiation pattern with co-cross polarization are also given

1.Introduction

In present day scenario, the significance in the design and developing the compact, inexpensive planar antennas with wide bandwidths are fuelled by rapid developments of various communication services and other wireless services. Hence, compact microstrip slot antennas have found increased usage in wireless applications specifically in S and C band wireless frequency range.

Several researchers have focused on improving various antenna parameters such as impedance bandwidth enhancement [1] and size reduction [2] of microstrip antennas. Bandwidth enhancement techniques that have been studied for planar antennas include the use of a thick substrates, parasitic patches, E-slot patch, H-shaped patch, U-shaped slot patch, T-shaped parasitic strip, meandered slot and slit loaded and shorting pins [3]. Also, several methods for reducing the size (compact) of the microstrip antenna have already been studied [4, 5, 6, 7, 8 and 9]. It is known that, the resonant frequency of a patch antenna is inversely proportional to dielectric constant. It is also possible to reduce the resonant frequency by using a substrate with high dielectric constant [10]. The rectangular U-slot patch antenna with a folded patch feed [11] and E-H shaped patch antenna with L-probe feed had been studied practically [12]. By cutting a square slot at the centre of a rectangular microstrip patch, both compactness and dual frequency operation can be achieved [13].

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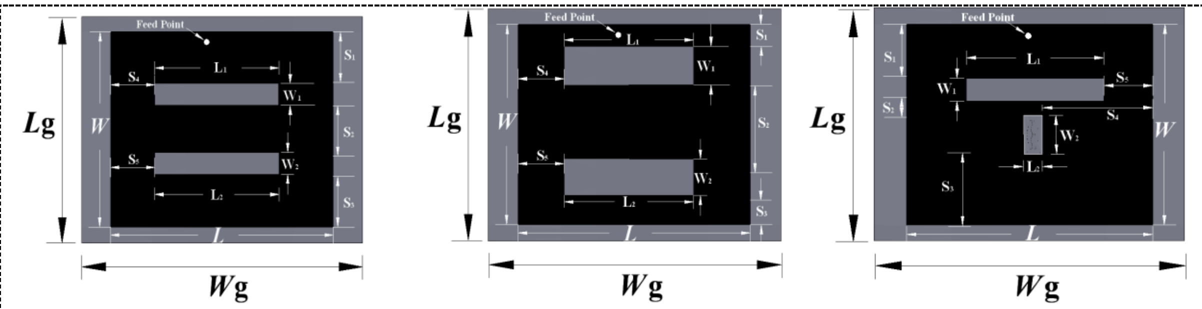
Journal of Physics: Conference Series **435** (2013) 012022 doi:10.1088/1742-6596/435/1/012022

By loading a pair of narrow slots parallel and close to the radiating edges of a bow-tie patch, dual-frequency operation with tunable frequency-ratio can be achieved [14].

A circularly polarized, dual-frequency, slotted square patch with probe feeding mechanism is reported to operate as the telemetry, telecommand and control (TT&C) antenna for satellite spacecrafts at 2.25 GHz and 3.0 GHz [15]. A compact patch design for circular polarization application based on third iteration minkowski-like pre fractal geometry to be used in dual band application was reported by Ali Jalal [16]. Two short-circuited microstrip patch antennas can radiate at dual frequencies was reported by Roy and Thomos [17]. A trade-off is taken among these techniques and optimized geometries are developed in this study. This paper demonstrates a technique to achieve both bandwidth enhancement and reduction of antenna structural profile. It is achieved by a novel design of wide slots along the radiating edges of the microstrip patch fabricated on low cost FR4 dielectric material.

2. Design structure of planar microstrip slot antennas

Figure 1 (a), (b) and (c) illustrate the fabricated planar microstrip slot antennas (MSSA) with length L = 17.76 mm, width W = 23.28 mm etched on FR4 dielectric material with dielectric constant ϵ_r = 4.4 and thickness h = 1.6 mm were designed using computer software AutoCAD-2010. Because, the dimensions of the patch are finite along the length and width, the fields at the edges of the patch undergo fringing. Most of the electric field lines reside in the substrate and the part of some lines exist in air. Since some of the waves travel in the substrate and some in air, an effective dielectric constant ϵ_{eff} is introduced to account for fringing. The amount of fringing is a function of the dimensions of the patch and the thickness of the substrate. The designed frequency of the patch antenna is 3.85 GHz. The RF power is fed to the radiating element (patch) by using the coax feed technique. It is a very common technique used for exciting microstrip antenna. The inner conductor of the coaxial feed connector extends through the dielectric and is soldered to the radiating element, whereas the outer conductor is connected to the ground plane. The main advantage of this type of feeding technique is easy to fabricate, has low spurious radiation and the feed can be placed at any desired location on the patch to match with its input impedance [18]. The coax feed is placed on the axis of symmetry to provide a good impedance matching. The feed position has been chosen at a distance $X_f = L/2[\epsilon_{eff}(\mathrm{sqrt}(L))]^{1/2}$, as given by M. Kara [19]. The copper plate is used as ground plane with dimension 35 x 35 mm having thickness 0.16 cm. The pair of slots are etched along the radiating and non - radiating edges of the radiating element, which is finally structured as microstrip slot antennas 1, 2 and 3 (MSSA 1, MSSA 2 and MSSA 3) with its slot dimensions in length (L_1, L_2), width (W_1, W_2) and spacing between slots (S_1, S_2, S_3, S_4, S_5). For MSSA 1, $L_1 = L_2$ = 17.16 mm, $W_1 = W_2$ = 2.87 mm, $S_1 = S_3$ = 8.04 mm S_2 = 3.77 mm, $S_4 = S_5$ = 2.78 mm as shown in figure 1.



(a) (b) (c)

Figure 1. Microstrip slot antenna (MSSA). (a). MSSA 1, (b). MSSA 2 and (c) MSSA 3.

For MSSA 2 as shown in figure1, the slot dimensions are $L_1 = L_2$ = 18.14, $W_1 = W_2$ = 3.86 mm, $S_1 = S_3$ = 5.17 mm, S_2 = 7.54 mm, $S_4 = S_5$ = 1.68mm and for MSSA 3 as shown in figure 1, the slot dimensions are L_1 = 18.14 mm, L_2 = 3.2 mm, W_1 = 3.86 mm, W_2 = 7.51 mm, S_1 = 5.16 mm, S_2 = 2.01 mm, S_3 = 9.04 mm, S_4 = 8.17 mm, S_5 = 2.68mm. The antennas resonate at two independent frequencies signifying dual band frequency characteristics. Slot lengths, widths and spacing dimensions are functions of operating wavelength λ_o.

3. Results and discussions

Good antenna performance can be achieved by using a thick dielectric substrate and having a low dielectric constant. It is desirable for obtaining improved bandwidth, high efficiency and good radiation characteristics leading to larger antenna size. Designing a compact antenna requires higher dielectric constant, leading to narrower bandwidth, lesser efficiency and higher loss tangents (dissipation factors) [18]. Hence, the final design in this paper required a trade-off between antenna dimensions and antenna performance, depending on the system requirement. In this design, the use of pair of broad slots on the radiating element (patch) are etched and it appear as discontinuity to the microstrip transmission line and provide a transverse component of current, which generates a longitudinal component of the magnetic field and is modelled as series inductance [20], so the electrical length of the patch increases, thus lowering the resonant frequency to achieve compactness of the antenna for fixed frequency operation. The antenna incorporated with the slots also has an advantage that it introduces a capacitance that suppresses some of the inductance introduced by the coax feed due to the thick substrate. The upper conducting layer, i.e., the patch element of the antenna is the source of radiation and it radiates primarily because of the fringing fields between the patch edge and the ground plane. The lower conducting layer acts as a perfectly reflecting ground plane, bouncing energy back through the substrate and into the free space. The various parameters of the fabricated microstrip slot antennas (MSSA) are measured on Vector Network Analyzer (Rohde and Schwarz, Germany make ZVK model 1127.8651) which has a operating frequency range starting from 30 MHz to 40 GHz.

The pair of narrow slots of MSSA 1 as shown in figure 1 resonates at two frequencies; at 3.51 GHz with return loss (RL = – 14.10 dB) and at 4.52 GHz (RL = – 17.14 dB) signifying dual band nature is depicted in figure 2. An impedance bandwidth of 230 MHz (5.8 %) and 140 MHz (3.9 %) are obtained at these two independent resonant frequencies with a moderate gain of 5.6 dB and 4.3 dB. MSSA 2 also resonates at two frequencies; at 3.81 GHz with return loss (RL = – 16.58 dB) and 5.16 GHz (RL = – 15.21 dB) as shown in figure 2 with achievable impedance bandwidth of 280 MHz (7.5 %) and 170 MHz (4.6 %) and a moderate gain of 3.7 dB and 4.9 dB. Due to the pair of wide slots printed on MSSA 2, the impedance bandwidth is increased to 280 MHz compared to impedance bandwidth of MSSA 1. As shown in figure 1 (c), when one horizontal and vertical slots are printed, the MSSA 3 resonates at two lower frequencies compared to MSSA 1 and MSSA 2; i.e., at is 2.22 GHz with return loss (RL = – 24.98 dB) and 3.68 GHz (RL = – 19.89 dB) with achievable impedance bandwidth of 195 MHz (4.9 %) and 260 MHz (5.6 %) with a peak gain of 5.75 dB and 7.58 dB.

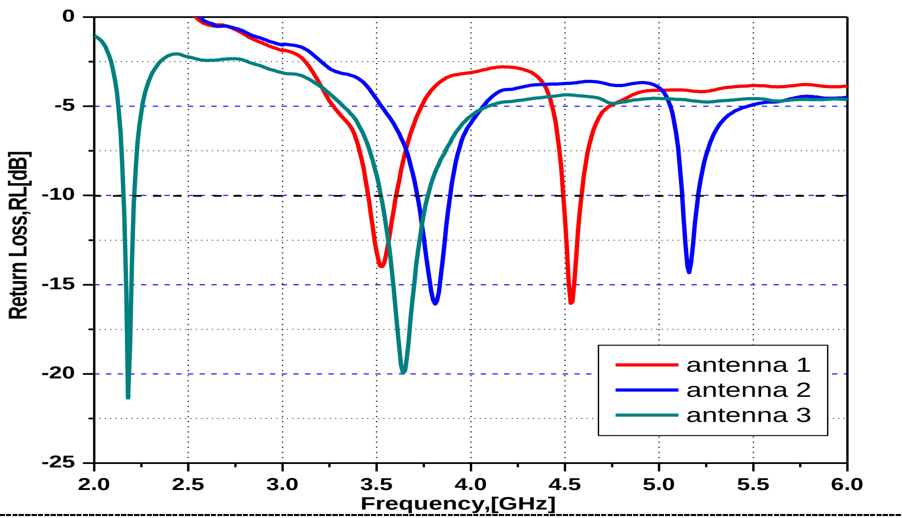


Figure 2. Return loss (RL) characteristics versus frequency

These two independent resonances for MSSA 1, 2 and 3 are produced due to the presence of slots on the radiating element. A compactness of 21 %, 15 % and 58 % are also achieved for MSSA 1, MSSA 2 and MSSA 3. From the return loss characteristics, the proposed antennas showed a lower resonant frequency with minimum return loss by varying slot length and width and spacing of the slots compared to the standard microstrip antenna. It is observed that there is a reduction in resonant frequency of MSSA 1, 2 but MSSA 3 showed a maximum lower resonant frequency of 2.22 GHz compared to the designed frequency 3.85 GHz making the antenna compact by 58 % with better return loss, improved impedance bandwidth and gain. Figure 3 shows the measured radiation patterns for the proposed microstrip slot antennas 1, 2 and 3 (MSSA 1, MSSA 2 and MSSA 3) with co-polar and cross-polar characteristics. The radiation patterns are measured and plotted at respective resonant frequencies 3.51 GHz and 4.52 GHz for MSSA1, 3.81 GHz and 5.16 GHz for MSSA 2 and 2.22 GHz and 3.68 GHz for MSSA 3. As shown in figure 3, the proposed antennas exhibited nearly omni-directional radiation patterns suitable for various wireless applications. MSSA 3 is the best antenna among the MSSA 1 and MSSA 2 in terms of compactness.

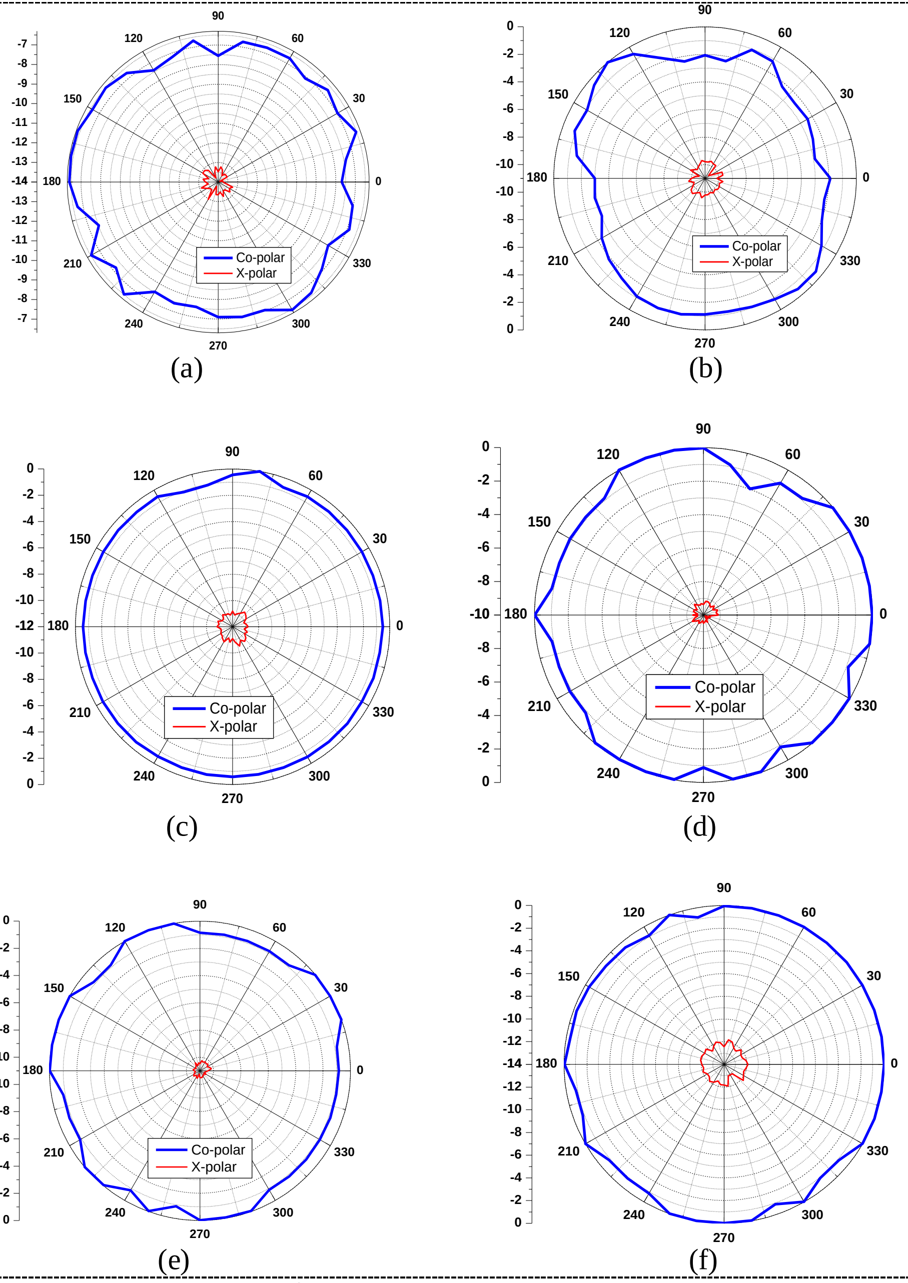


Figure 3. Measured radiation patterns of the microstrip slot antenna (MSSA). (a) MSSA 1 at 3.51 GHz, (b) MSSA 1 at 4.52 GHz, (c) MSSA 2 at 3.81 GHz, (d) MSSA 2 at 5.16 GHz, (e) MSSA 3 at 2.22GHz, (f) MSSA 3 at 3.68 GHz.

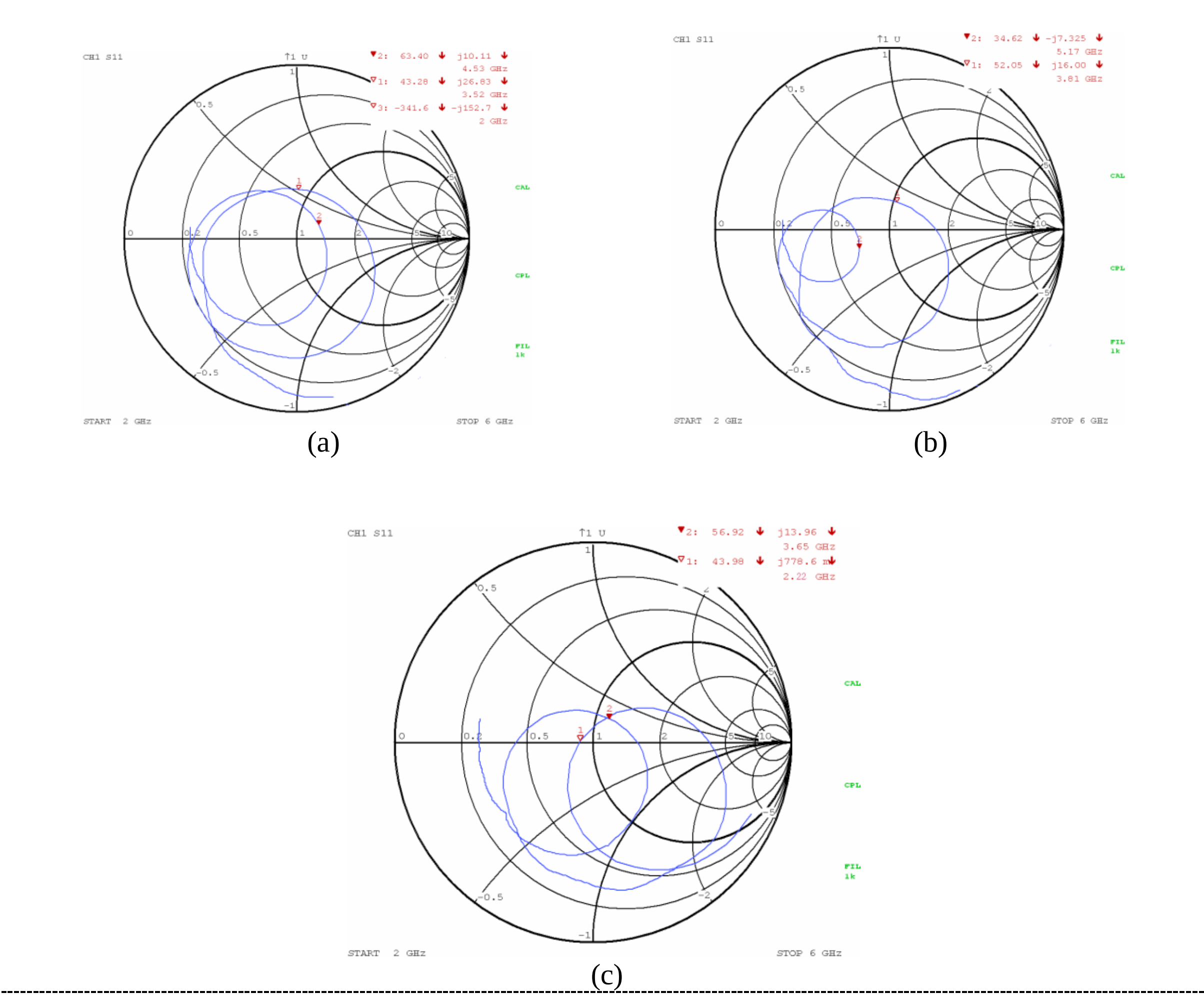


Figure 4. Smith chart plot of (MSSA). (a). MSSA 1, (b). MSSA 2 and (c) MSSA 3.

Figure 4 (a), (b) and (c) shows the Smith chart plots of impedance locus versus frequency for the proposed microstrip slot antennas 1, 2 and 3 (MSSA 1, MSSA 2 and MSSA 3). The presence of two loops on the Smith chart shows dual band characteristics. Hence, the design parameters of the antenna lead to good impedance matching between the input and the load in S and C band frequency range.

4.Conclusion

The proposed antennas are rugged and have low cost and moderate gain suitable for RADAR, WLAN, fixed satellite services, maritime mobile services and space applications covering 2 - 6 GHz frequency range. The microstrip slot antennas are compact, having a size reduction of 21 %, 15% and 58 % with the peak gain of 7.58 dB. The proposed antennas also resonate at two frequencies in S band. This dual frequency behavior increases its applications in radar and satellite communications. The low impedance bandwidth of the antenna is attributed to the low loss tangent of the FR4 substrate material with higher gain.

Acknowledgments

Authors thank the Department of Science and Technology (DST), Government of India, New Delhi, for sanctioning Vector Network Analyzer to this Department under FIST Project and also providing financial assistance to Ambresh P.A under Rajiv Gandhi National fellowship- Junior Research Fellowship & Senior Research Fellowship (RGNF-JRF& RGNF-SRF) [No.F.14 (SC)/2009(SA-III) dated 18 November 2010] scheme by University Grants Commission, New Delhi.

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