Chapter 2
Estimation of Slot Position for a Slotted Antenna

Arnab Das, Chayan Banerjee, Bipa Datta and Moumita Mukherjee

Abstract Compact microstrip patch antennas have become quite popular nowadays. With lesser form factor requirements and for multiband applications, slotted antennas have proved useful. This paper evaluates the merits of slot positioning with respect to a fixed feed point. The evaluation is based on antenna parameters like resonating frequency, return loss and bandwidth. The simulations are run for a triangular (Δ) and a V slot. Results show that output characteristic follows almost similar in nature to slot positions with respect to fixed feeding point, irrespective of the slot shape. It is found that a slot produces maximum signal bandwidth and gain when put near the feeding point.

Keywords Microstrip antenna · Slot antenna · Slot positioning · Triangular slot · V-shaped slot

2.1 Introduction

In applications where size, weight, cost, performance, ease of installation and aerodynamic profile are constrains, low profile antennas like microstrip and printed slot antennas are required. Slot antennas exhibit wider bandwidth, lower dispersion

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and lower radiation loss than microstrip antennas [1–5]. It is better to have a single multiband antenna than to have different antennas to work at different frequencies. The most effective technique to design a multiband slot antenna is to cut a slot on the microstrip patch at a proper position and with the right dimensions. The dimensions, i.e. the length (L) of the conventional antenna determine the resonant frequency and the width (W) of the antenna has a predominant effect on input matching condition [1, 6].

The available literature clearly defines the slot antenna parameters like antenna geometry, feed line types, ground plane and substrate, but they do not provide any clear information about the positioning of the slot on the conductor plate of a slot antenna. In this paper we tried to evaluate the effect of changing of position (of a slot of arbitrary shape) on the antenna characteristics. The parameters include bandwidth, reflected impedance and resonant frequencies. For the sake of simplicity and analysis the antenna feed line is kept fixed at a corner of the substrate, throughout the entire evaluation.

2.2 Parameter with Antenna Geometry Selection

Microstrip lines feed and coaxial probe feed are popularly used in slot antenna design. The purpose of the feed is to carry energy from a connector to the actual antenna, so their proper placement is very crucial. Coaxial probe-feed (radius = 0.5 mm) is located at $W/2$ and $L/3$ to get faithful operation for a rectangular microstrip antenna [1]. From our experimental point of view, we choose feed point fixed at $P(-3.25, -1.7)$, with varying slot section positions in horizontal direction.

We have used two popular slot shapes for the evaluation of antenna characteristics, a triangular slot (Δ) and a V type (non-tapered) slot. Triangular slots and its variations (e.g. Vivaldi, Sierpinski triangle) are popular and are used in a lot of applications requiring multiband application. The slots are simulated for their output characteristics like return loss, bandwidth and resonant frequencies at different locations on the conductor. There are 14 discrete locations, considered from edge AB of the microstrip top conductor, while moving towards the feeding point.

Here, the used conventional antenna dimensions are L = 6 mm, W = 10 mm, substrate (PTFE) thickness h = 1.5847 mm, dielectric constant ε_r = 4.4 with coaxial probe-feed (radius = 0.5 mm) located at $P(-3.25, -1.7)$ (Fig. 2.1). The proposed V-shaped slot antenna (Fig. 2.2) and Δ-shaped slot antenna (Fig. 2.3), for both feed point is located at P $(-3.25, -1.7)$.

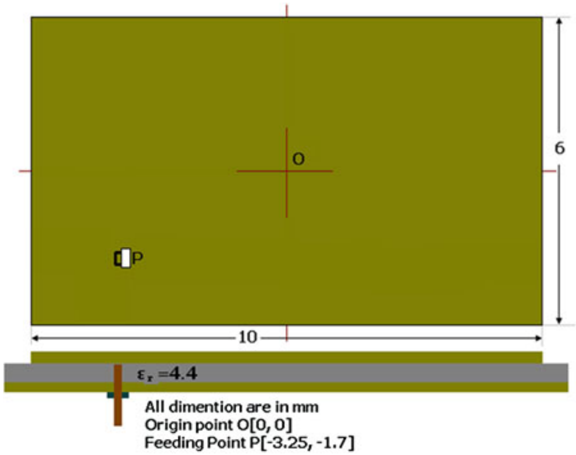

Fig. 2.1 Conventional microstrip antenna

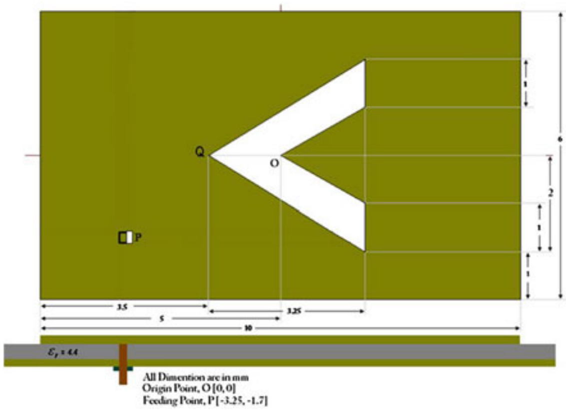

Fig. 2.2 V-slotted patch antenna

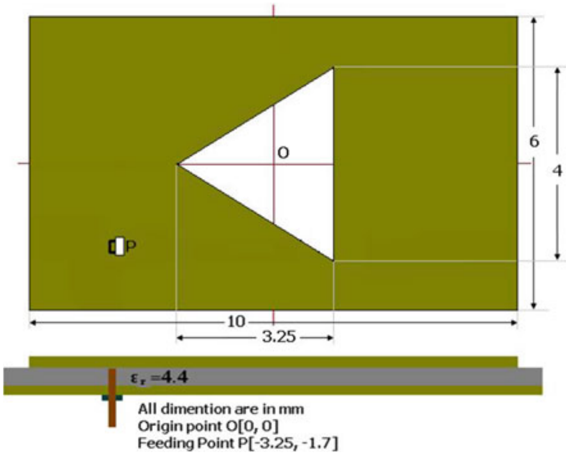

Fig. 2.3 Triangular slotted patch antenna

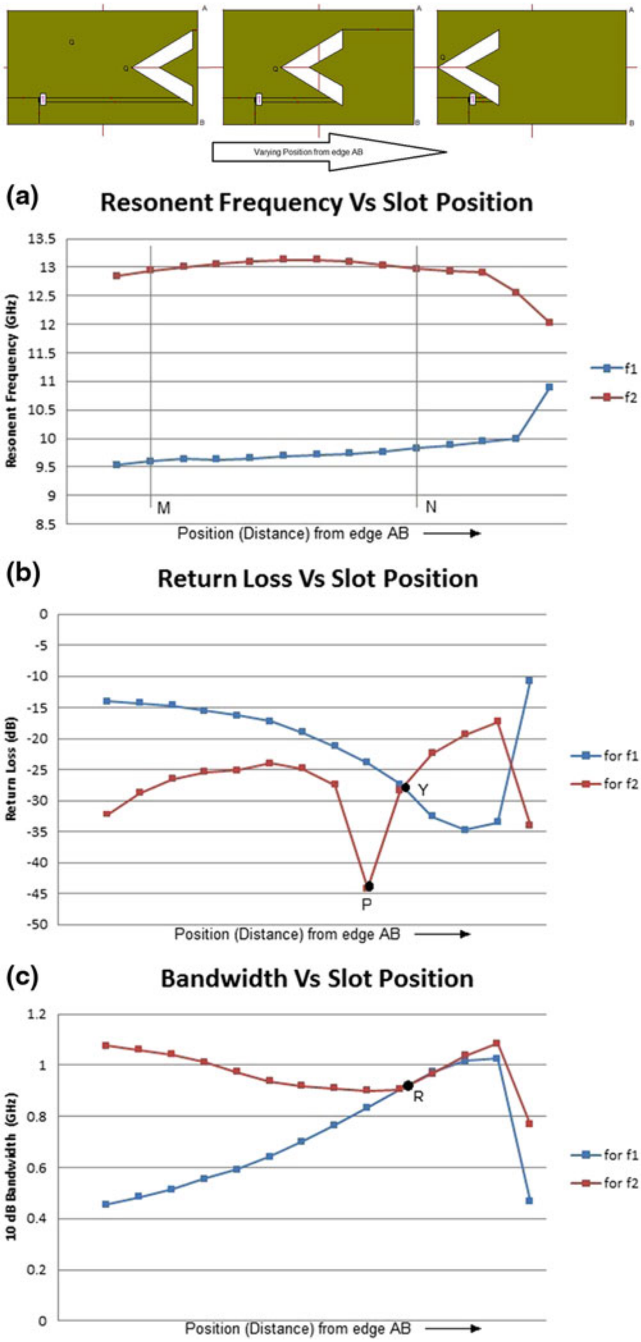

Fig. 2.4 Comparison plots of V slot antenna radiation characteristics. **a** Resonant frequency versus slot position. **b** Return loss versus slot position. **c** Bandwidth versus slot position

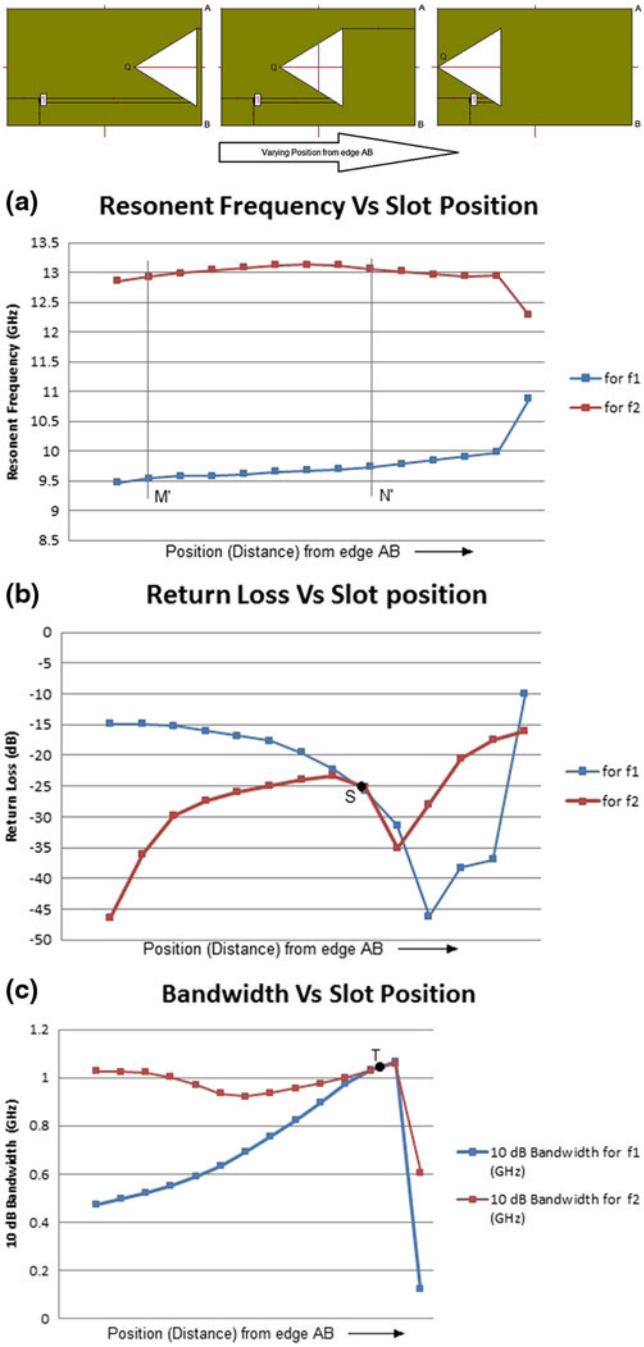

Fig. 2.5 Comparison plots of Δ slot antenna radiation characteristics. **a** Resonant frequency versus slot position. **b** Return loss versus slot position. **c** Bandwidth versus slot position

2.3 Simulation, Results and Discussion

The characteristics of the designed structures presented in this paper are simulated using MoM-based electromagnetic solver, IE3D.

Figures 2.4 and 2.5 show the effect of shifting the slots of two different shapes, away from the right edge AB of the top conductor (of a conventional antenna) towards the feeding point. Figure 2.4a–c shows the resonant frequency, return loss and 10 dB bandwidth plots, respectively, for the V-shaped slot at different positions. Figure 2.5 shows the same kind of plots but with respect to a triangular slot.

Considering a slot antenna (V or Δ), we can see that the two resonant frequencies (Figs. 2.4a or 2.5b) make it suitable for multiband operation. Dual band applications can be efficiently carried out in the region MN or M′N′, as labelled in the plot. It is clear from the plot in Fig. 2.4b that dual band applications can be properly carried out at the point *Y*. At *Y* the return losses due to the two resonant frequencies are around −30 dB and hence comparable to each other. It is also observed that the return losses due to the two resonant frequencies reach their minima at two extreme positions of the slot.

Bandwidth analysis in Figs. 2.4c and 2.5c shows that higher bandwidth can be obtained for both the resonant frequencies at point *R* and *T*, respectively, paving the way for dual band application. Tables 2.1 and 2.2 and Figs. 2.6 and 2.7 show the comparison of important parameters like the 10 dB bandwidth and the return loss for the two types of slots considered for evaluation.

Table 2.1 Comparison of resonant frequency (f_1 and f_2)

Various antennas (Varying reference point position)	Resonant frequency for: (f_1—1st resonant freq. and f_2—2nd resonant freq.)			
	V slot antenna		Δ slot antenna	
	f_1 (GHz)	f_2 (GHz)	f_1 (GHz)	f_2 (GHz)
Conventional antenna	10.0696	13.1724	10.0696	13.1724
Q (1.5, 0)	9.53809	12.8487	9.46265	12.8488
Q (1, 0)	9.59556	12.9425	9.53849	12.9249
Q (0.5, 0)	9.6333	13.0007	9.58026	12.9819
Q (0, 0)	9.63261	13.0595	9.57677	13.0388
Q (−0.5, 0)	9.65341	13.0952	9.61185	13.077
Q (−1, 0)	9.69033	13.1313	9.65266	13.1153
Q (−1.5, 0)	9.70882	13.1326	9.6732	13.132
Q (−2, 0)	9.72973	13.0962	9.69168	13.1153
Q (−2.5, 0)	9.76746	13.039	9.72994	13.0621
Q (−3, 0)	9.82499	12.9731	9.78616	13.0201
Q (−3.5, 0)	9.88172	12.9266	9.84385	12.9627
Q (−4, 0)	9.93883	12.9146	9.90101	12.9405
Q (−4.5, 0)	9.99595	12.5511	9.97696	12.9412
Q (−5, 0)	10.8884	12.0311	10.8694	12.2787

Table 2.2 Comparison of important parameters

	Q position	10 dB BW		Return loss	
		V	Triangle	V	Triangle
Position (distance) from edge AB ↓	*Reading at resonant frequency f_1*				
	(1.5, 0)	0.45489	0.47215	−13.9808	−14.9224
	(1, 0)	0.48469	0.49773	−14.2307	−14.9037
	(0.5, 0)	0.51355	0.52207	−14.6223	−15.178
	(0, 0)	0.55468	0.55139	−15.5391	−15.9629
	(−0.5, 0)	0.593	0.58911	−16.2733	−16.7812
	(−1, 0)	0.64135	0.63294	−17.2323	−17.6743
	(−1.5, 0)	0.70045	0.69045	−19	−19.5895
	(−2, 0)	0.76585	0.75495	−21.2624	−22.2803
(max)	(−2.5, 0)	0.83395	0.82379	−23.8892	−25.7986
	(−3, 0)	0.90472	0.89856	−27.3633	−31.3659
	(−3.5, 0)	*0.97357*	*0.97572*	*−32.518*	*−46.1489*
	(−4, 0)	1.01592	1.03495	−34.7746	−38.3037
	(−4.5, 0)	1.0258	1.06903	−33.4651	−36.9497
	(−5, 0)	0.4663	0.122	−10.7416	−10.0672
	Reading at resonant frequency f_2				
	(1.5, 0)	1.0759	1.0259	−32.1745	−46.4336
	(1, 0)	1.0596	1.0234	−28.7547	−35.9967
	(0.5, 0)	1.0407	1.0206	−26.509	−29.7632
	(0, 0)	1.0112	1.0015	−25.3984	−27.3375
	(−0.5, 0)	0.974	0.9706	−25.1344	−25.9813
	(−1, 0)	0.9368	0.9335	−23.9716	−24.93
	(−1.5, 0)	0.9178	0.922	−24.7998	−23.8736
	(−2, 0)	0.9097	0.9362	−27.4495	−23.2671
	(−2.5, 0)	0.9009	0.9568	−44.1331	−25.0709
	(−3, 0)	0.9052	0.9759	−28.3544	−34.9831
	(−3.5, 0)	*0.9656*	*0.9989*	*−22.3528*	*−28.0403*
	(−4, 0)	1.0361	1.02982	−19.39	−20.4924
	(−4.5, 0)	1.0856	1.0584	−17.2511	−17.4633
	(−5, 0)	0.7676	0.6049	−34.0197	−16.0221

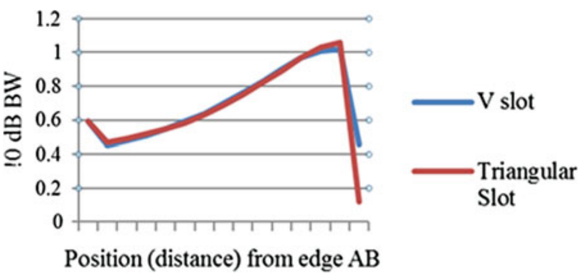

Fig. 2.6 Bandwidth versus position plots for Δ and V slots, for f_1

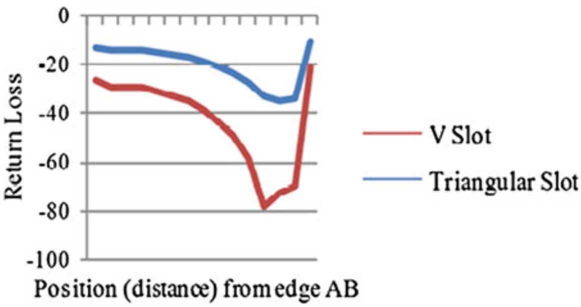

Fig. 2.7 Return loss versus position plots for Δ and V slots, for f_1

2.4 Conclusion

Positioning of the slot is crucial for the efficiency of a microstrip antenna. This paper evaluated the output characteristics of a slot antenna. The simulations are made with a fixed feeding point and two types of slot shapes. The slot positions were varied from one edge of the radiating conductor (AB), while moving towards the feeding point. The gain is maximum when the vertex (Q) of the slot is almost above the feeding point, but gain value falls drastically as the vertex crosses the feeding point. A similar nature is shown by return loss and bandwidth. It may be concluded that if the slot (irrespective of shape) is moved towards a fixed feeding point along the x axis (without moving in Y axis), then the antenna gives a maximum bandwidth and gain with slot is placed near the feed point. Return loss values though may differ in the location of their maxima and minima from slot to slot and depending on their resonant frequencies.

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