

# Compact Rectangular Microstrip Antenna with Open End Meandering Slots in the Ground Plane for Bandwidth Enhancement

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**Abstract**—In this paper, a compact rectangular microstrip antenna with open end meandering slots in the ground plane for bandwidth enhancement is presented. The design consists of three identical narrow open end meandering slots embedded in the antenna's ground plane parallel to the radiating edge of the rectangular patch. Experimental study was carried out by varying the length of open end slots. Using open end meandering slots in the groundplane, the lower frequency of the antenna has been greatly lowered having large enhancement in bandwidth. With the proposed design, when compared to standard rectangular microstrip antenna without slots, an extreme reduction of 83% in the antenna size is obtained with a broad bandwidth of 38.3% (-10 dB return loss).

## I. INTRODUCTION

Modern communication devices and applications such as mobile cellular handsets, cordless phones, blue tooth devices and WLAN's call for an extreme compact antenna covering a wide operational bandwidth. Microstrip antennas are attractive as they have several advantages like low cost, low profile planar configuration. But the antenna size is large for operation in the frequency bands of mentioned applications. Moreover the bandwidth of microstrip antenna is relatively narrow. Many techniques have been reported for reducing the size of the microstrip antenna. Meandering of the patch by loading several slits in the nonradiating edges is proved to be one of the effective method in reducing the size of the microstrip antenna [1-2]. It is found that the narrow meandering slots increase the effective electrical length of the patch which in turn reduces the size of the antenna operated at a given frequency. But, at the same time there is reduction in the bandwidth as well. To overcome this problem, meandering technique is applied to the ground plane of the microstrip antenna [3]. In this letter, a similar significant lowering of the antenna's fundamental resonant frequency to that of patch-meandering method is achieved. Moreover, the impedance bandwidth and gain of the antenna were also enhanced. This was a great advantage of ground-meandering method over the patch-meandering. However, the obtained bandwidth is comparatively very less to meet the

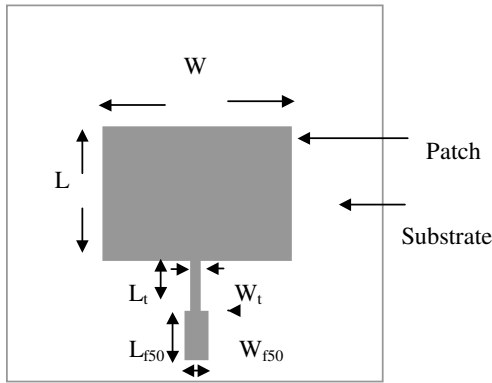
requirements of the above said applications. Therefore, further improvement in the bandwidth and compactness of antenna is very much needed. Hence many combinations of radiating patch and the ground plane slots have been configured to achieve extremely compact and broadband antenna. T. W. Chiou *et al* [4] introduced open end meandering slots in the ground plane that helped to reduce the overall size and increasing the bandwidth. Recently broadening of the lower operational frequency band was achieved using two open end slots under the radiating element (inverted F-type patch) [5]. It was found that the use of two parallel open-end slots in the ground plane decrease the resonant frequency of the ground plane and enhance the bandwidth of the lower operational frequency band. Here a bandwidth of 50% for -6 dB return loss is achieved.

In this paper, we present a compact rectangular microstrip antenna with open end meandering slots in the ground plane for bandwidth enhancement. Three identical narrow open end slots are embedded in the antenna's groundplane and are aligned with an equal spacing of  $L/4$  parallel to the rectangular patch's radiating edge. Experimental study was carried out for different open end slot lengths. Using three open end meandering slots, dual frequency operation was achieved with significant lowering of the both the resonant frequencies. Moreover, the lower frequency is greatly lowered with enhancement in bandwidth. With the proposed design a broad bandwidth of 38.3% (-10 dB return loss) is achieved with extreme reduction of 83% in the antenna size when compared to conventional microstrip antenna. The achieved bandwidth and size reduction are more than that achieved by R. Hossa *et al* [5].

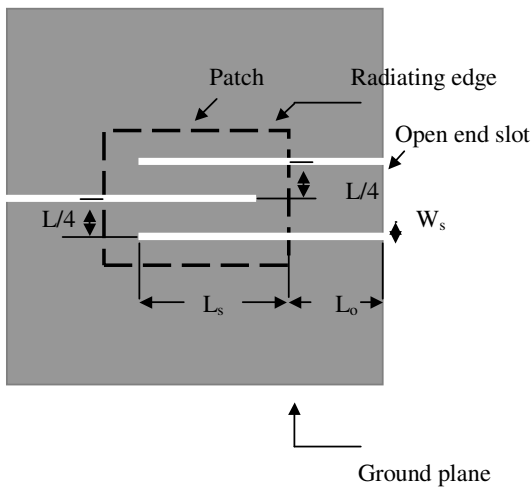
## II. ANTENNA DESIGN

First, a reference antenna (RA) i.e., a rectangular microstrip antenna of size  $(L, W) = (11.33, 15.24)mm$  [6] fed by a  $50\Omega$  center fed microstrip line feed,  $(L_{f50}, W_{f50}) = (6.187, 3.060)mm$ , through a quarter wave transformer having  $(L_t, W_t) = (4.922, 0.500)mm$  is designed for operating frequency of 6 GHz ( $\epsilon_r = 4.4$  and  $h = 1.6 mm$ ) for  $TM_{10}$  mode [7] as shown in Fig. 1(a). Here the microstrip line feed is used to excite the

patch as the planar feed makes the structure suitable for integration with associated microwave circuitry. Later three identical narrow open end slots were embedded in the antenna's ground plane that were aligned with an equal spacing of  $L/4$  parallel to the radiating edge of the rectangular patch as shown in Fig. 1(b). The embedded open end slots are narrow ( $W_s = 1 \text{ mm}$ ) and have a slot length of  $L_s + L_o$ .  $L_s$  and  $L_o$  are the slot lengths inside and outside the projection image of the radiating patch in the ground plane respectively. The slot length  $L_o$  for the prototypes is fixed to be 11.2 mm (as the groundplane size is  $38 \times 38 \text{ mm}$ ) while the slot length  $L_s$  is varied from 3.5 to 14 mm with the interval of 3.5 mm and studied in detail. However, for the reference antenna  $L_s = L_o = 0$ .



(a)



(b)

Fig. 1: Geometry of a compact rectangular microstrip antenna with meandering open end slots in the ground plane. (a). Top View, (b) Rear View.

### III. EXPERIMENTAL RESULTS

The Prototype antennas with the above said geometry have been constructed and measured experimentally using Rohde and Schwarz, Germany make Vector Network Analyzer of ZVK model. (10MHz to 40 GHz). The obtained results are tabulated in Table 1.

Table 1: Measured results of compact rectangular microstrip antenna with meandering open end slots in the ground plane.

$L_o$ (mm)	$L_s$ (mm)	$f_r$ (GHz)	Return loss (dB)	Band Width (MHz, %)	Reduction in size (%)
0	0	5.987	-18.50	275, 4.5	-
11.2	3.5	$f_1 = 3.016$ $f_2 = 5.822$	-28.40 -16.69	31, 1 77, 1.3	52.2 7.7
11.2	7	5.047	-25.02	210, 3.9	19.6
11.2	10.5	$f_1 = 1.451$ $f_2 = 2.195$	-18.71 -16.42	93, 6.4 15, 0.7	77 66.3
11.2	14	$f_1 = 1.071$ $f_2 = 1.826$	-22.76 -11.99	410, 38.3 ~26, ~1.45	83 71.86

Table 1 shows that the reference antenna ( $L_s = L_o = 0$ ) resonating for 5.987 GHz having a bandwidth of 4.5% (-10dB return-loss).

As shown in the table, with increase in the slot length,  $L_s$ , from 0 to 3.5mm, it is seen that compact dual frequency operation is obtained with lowering in both the resonant frequencies having a frequency ratio of 1.9.  $f_1$  gives a compactness of 52.2% in size while  $f_2$  gives a compactness of 7.7%. The corresponding bandwidths are also tabulated in Table 1. From the table it is found that there is large reduction in the bandwidth of both the frequencies in comparison with the reference antenna of this slot length.  $f_1$  has a bandwidth reduction of 77% and  $f_2$  has a reduction of 71% when compared to reference antenna. Here the bandwidth of  $f_1$  is less than  $f_2$ .

When  $L_s = 7 \text{ mm}$ , i.e.,  $L_s = 0.46 W$  the frequencies  $f_1$  and  $f_2$  merge together and the antenna resonates at single frequency which is 0.84 times that of the reference antenna giving a size reduction of 19.6%. The bandwidth is also reduced by 13% when compared to reference antenna.

Later when  $L_s = 10.5\text{mm}$ , once again compact dual frequency operation is obtained with significant lowering in both the frequencies having a frequency ratio of 1.51. In this case  $f_1$  gives a size reduction of 77% while  $f_2$  gives 66.3%. It is also found that the bandwidth of  $f_1$  is increased by 1.42 times (29% more) more than the reference antenna where as  $f_2$  has reduction in the bandwidth of 84% when compared to reference antenna. Here,  $f_1$  has slightly more bandwidth when compared to  $f_2$ .

With further increase in the slot length, i.e., when  $L_s = 14\text{mm}$  or  $L_s = 0.91\lambda$ , there is still further reduction in the both the frequencies. Here  $f_1$  resonates at a frequency which is 0.17 times the reference antenna giving a size reduction of 83% and  $f_2$  resonates at a frequency which is 0.30 times the reference antenna giving a compactness of 71%. Moreover the bandwidth of  $f_1$  is found to be further increased over the bandwidth of  $f_2$ . Fig. 2 shows that the lower frequency  $f_1$  splits into two adjacent dual frequencies whose frequency

bands merge together giving a wide operational bandwidth. From the table a calculated bandwidth of 38.3% is obtained. The obtained bandwidth is 8.51 times (88.2 %more) the bandwidth of the reference antenna. But at the same time  $f_2$  starts diminishing. It is also found that for larger open end meandering slots in the ground plane there is a significant improvement in the return loss characteristics of antenna.

Typical copolarized radiation pattern of the proposed antenna, i.e., when  $L_s = 14\text{mm}$ , for  $f_1 = 1.041\text{GHz}$  has been measured for H-plane and E-plane and is potted in Fig. 3 It seen from the figure that the proposed antenna presents a good broadside radiation pattern. The variation in the E-plane pattern is smoother than that in the H-plane pattern. A measured gain of 4.1 dB for the proposed antenna is obtained.

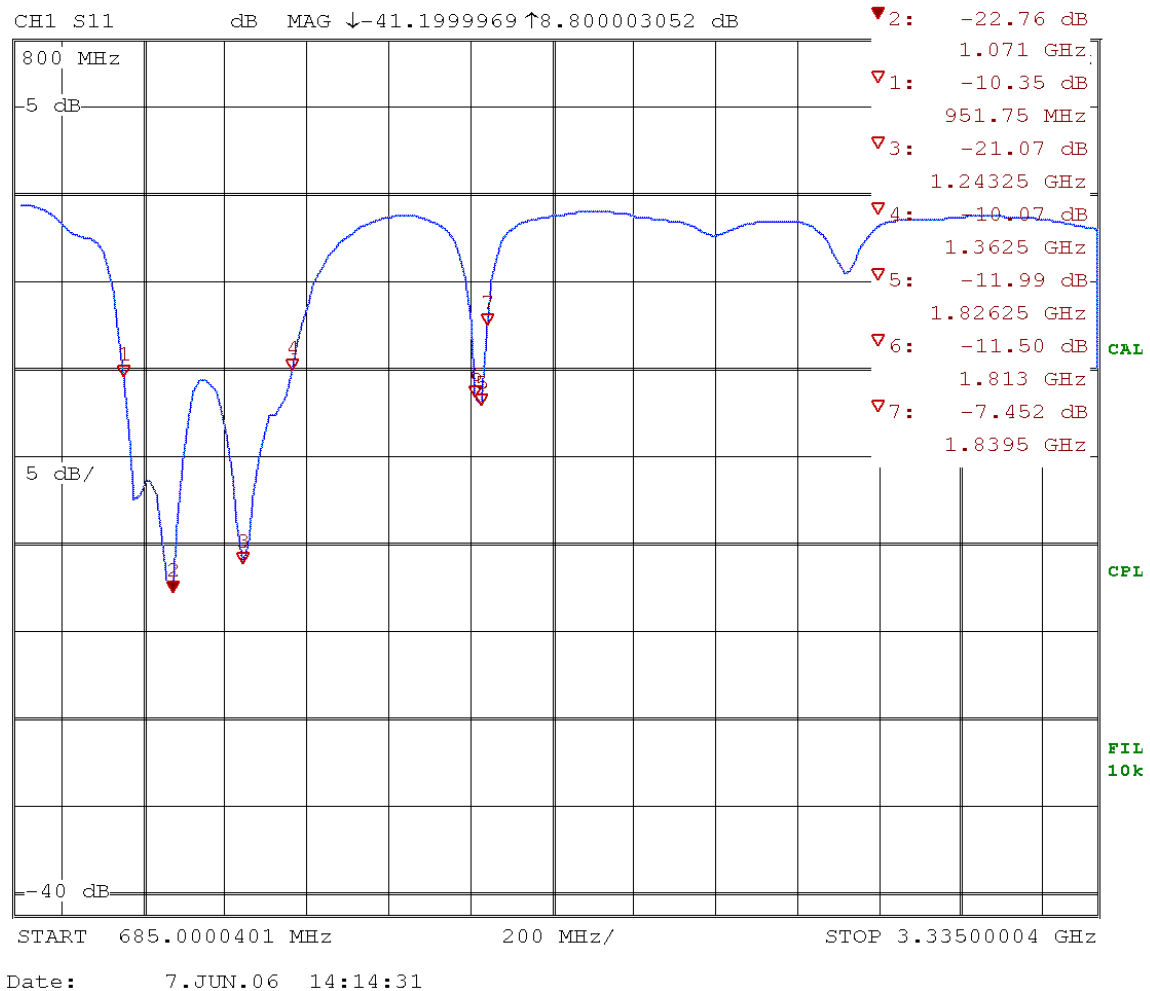


Fig.2: Variation of return loss with frequency for compact rectangular microstrip antenna with meandering open end slots in the ground plane ( $L_s = 14\text{mm}$ ).

#### IV. CONCLUSIONS

Compact rectangular microstrip antenna with open end meandering slots in the ground plane is presented and studied in detail. It is found that by inserting open end meandering slots in the ground plane, lower frequency is significantly lowered having large enhancement in the bandwidth. With the proposed design a bandwidth is 38.3% (-10 dB return loss) and an extreme reduction of 83% in the antenna size are obtained.

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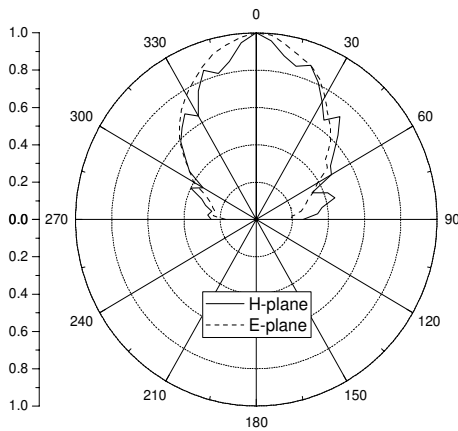


Fig.3: Copolarized radiation pattern of compact rectangular microstrip antenna with meandering open end slots in the ground plane ( $L_s = 14mm$ ) at  $f_1 = 1.041$  GHz.

Fig. 4 shows the measured resonant frequencies against the slot length ( $L_s$ ). From the figure, initially as the slot length increases from 0 to 3.5mm, it is seen that the antenna resonant frequency lowers and the antenna resonant for dual frequencies  $f_1$  and  $f_2$  giving compact dual-frequency operation. It can also be seen that the lowering of resonant frequency is more significant in case  $f_1$ . Again for further increase in the slot length from 3.5mm to 7mm,  $f_2$  slightly decreases but  $f_1$  starts increasing toward  $f_2$ . They both merge with each other and resonant at single frequency. Later for the further increase in the slot length to 10.5mm, an instant lowering of both the resonant frequencies is observed. Again for further increase in the slot length, the resonant frequency of the both frequencies decreases gradually.

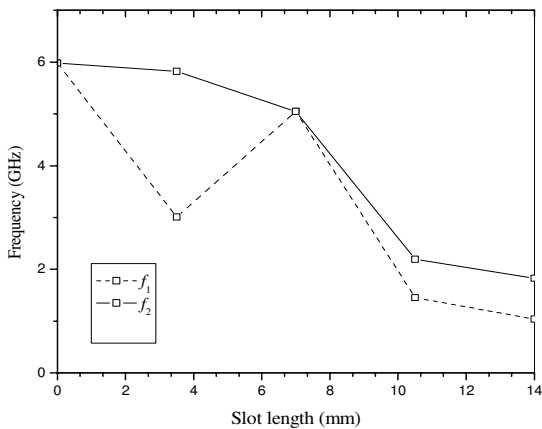


Fig. 4: Measured resonant frequency against slot length for antennas.