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Study and Analysis on Compactness of Patch Antenna Utilizing Ground Plane with U slot

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This article examines and studies the impacts of a U-shaped slot in the ground plane of a rectangular microstrip patch antenna with a finite ground plane. To build a compact patch antenna, the U-shaped slot's ideal size and placement have been considered. The size of the patch is 10.6×7.8 mm^2 and the size of the overall rectangular antenna structure is only 31.8×23.4 mm^2 including modified ground backside plane. The reference antenna's resonant frequency is 10 GHz and after the incorporation of U-shaped slot at the ground plane that resonant frequency lowered to 2.1 GHz. By the parametric studies almost 96 % compactness has been found possessing the slot's optimum dimension. The improved antenna's gain has been identified as 2.5 dBi. In this literature a study on compactness of rectangular microstrip antenna has been discussed and the effects of U-shaped slot on the finite ground plane over the resonant frequency, return loss and bandwidth have been analyzed. By adjusting various slot parameters in parametric research and selecting the best value of slot's dimension and position, it has been determined that the modified antenna's resonance frequency is 2.1 GHz.

Keywords: Rectangular Microstrip Antenna, Compactness, U-slot

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1. INTRODUCTION

The microstrip patch antenna use is prevalent in portable devices for wireless communication systems. For lower frequency bands like L and S band operation the size of the microstrip antenna becomes large and it is difficult to fit within small devices. But to make it miniaturized size, several modifications have been carried out and maintain the small antenna size even for lower frequency band applications. So the investigation on compactness of the antenna is one of the most important field of research.

The researchers have embraced certain methods for lowering the frequency of resonance. Very usual process of getting compact antenna is to increase the electrical path length so that resonant frequency is decreased. To increase the current route on the patch, numerous slots have been sliced into the radiating patch in this technique [1-3]. The modification on the ground plane also keeps the effect on lowering the resonant frequency. In some literature single slotted ground plane, asymmetric rectangular slot incorporation on the ground have been designed to obtain the compact microstrip antenna [4-6]. Defected ground structure, monopole antenna structure are also other techniques to achieve lower resonant frequencies [7-9]. The conventional antenna's resonating frequency has been dropped considerably by using grounded strips, parasitic element in the form of L and T with the patch, spur lines besides the radiating element, small slotted ground structure with slotted patch etc. and almost 50% to 85% compactness were claimed in some articles [10-17].

In this literature a study on compactness of rectangular microstrip antenna has been discussed and the effects of U shaped slot on the finite ground plane over the resonant frequency, return loss and bandwidth have been analyzed. By adjusting various slot parameters in a parametric research and selecting the best value of slot's dimension and position, it has been determined that the modified antenna's resonance frequency is 2.1 GHz. The dimension of the antenna with ground plane is only 31.8×23.4 mm^2 and compared to the antenna's standard size for its resonance frequency of 2.1 GHz, almost 96 % compactness has been obtained. At 2.1 GHz, the antenna's gain has been determined to be 2.5 dBi.

2. ANTENNA DESIGN, PARAMETRIC STUDY

The reference antenna has been taken for the resonating frequency of 10 GHz with Arlon substrate having relative permittivity $\varepsilon_r = 3$ and the substrate's thickness $h = 1.524$ mm. The dimension of the patch has been calculated as 10.6×7.8 mm^2 and the ground plane's size has been taken as 31.8×23.4 mm^2. In the modified antenna structure a U-shaped slot is inserted inside the ground plane. Parametric analyses have taken the slot's size into account. The best placement for coaxial wire feeding in all the antennas has been chosen as optimum value. Fig. 1 and 2 depict the reference and modified antenna configurations.

The parameters correspond to the size of the U – shaped slot in the ground back plane are W_1, W_2, and W_3, and the values are 19 mm, 1 mm and 12 mm respectively which have been determined by parametric studies. The variation of W_1, W_2, and W_3 has been carried out keeping other parameter fixed. Determination of the value of W_1 by parametric study appears

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in Table 1 and Fig. 3 displays the corresponding graphical representations.

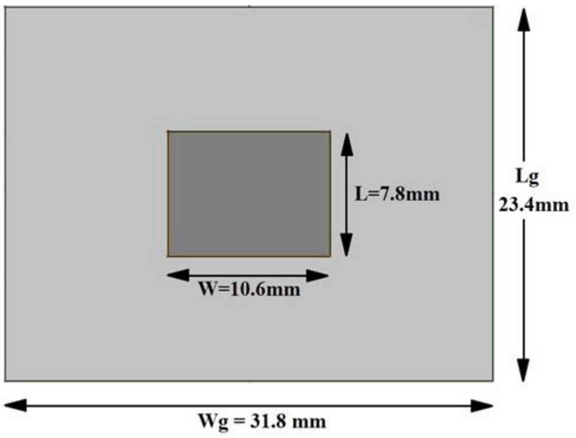

Fig. 1 – Reference antenna with finite ground

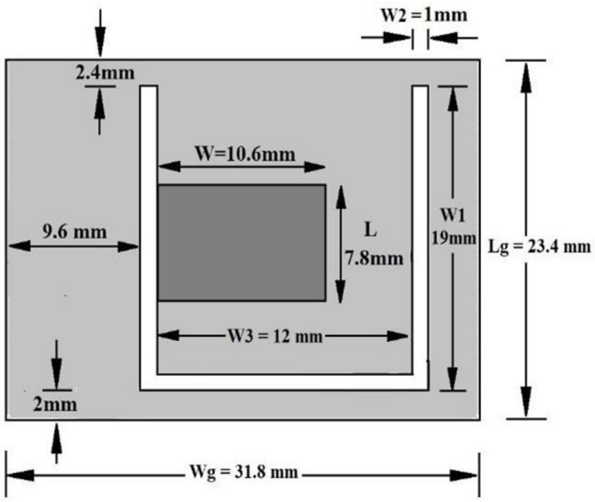

Fig. 2 – Modified antenna with U shaped slotted ground plane

Table 1 – Determination of the value of W_1 by fixing the W_2 = 1 mm and W_3 = 12 mm

Value of W1 in mm	**Resonating Fr in GHz**	**Return-loss in dB**	**BW in GHz**
19	***2.11***	***–28.5***	***0.01075***
18	2.32	–20.9	0.01077
17	2.4	–24.7	0.02054
16	2.51	–23.8	0.06531
15	2.62	–21.5	0.02531
14	2.71	–24.6	0.04188
13	2.8	–26.7	0.05235
12	3.14	–27.6	0.08309
11	3.41	–27.6	0.06849

The value of the W_2 has been finalized by taking the parametric studies displayed in Table 2 and Fig. 4 shows the relevant graphical representation.

The value of W_3 has been determined by the parametric studies with fixed value of $W_1 = 19$ mm and $W_2 = 1$ mm. The results are presented in tabular form in Table 3 and graphically in Fig. 5.

Table 2 – Determination of the value of W_2 by fixing the W_1 = 19 mm and W_3 = 12 mm

Value of W_2 in mm	**Resonating Fr in GHz**	**Return-loss in dB**	**BW in GHz**
0.2	2.87	–23	0.01095
0.4	2.67	–22.9	0.01089
0.6	2.56	–21.5	0.01085
0.8	2.5	–20.6	0.01081
1	***2.11***	***–28.5***	***0.01075***
1.2	2.12	–21.1	0.01068
1.4	2.14	–20.1	0.01064
1.6	2.12	–20.2	0.01023
1.8	2.18	–20	0.01058
2	2.23	–19.1	0.01098

Table 2 – Determination of the value of W_3 by fixing the W_1 = 19 mm and W_2 = 1 mm

Value of W_3 in mm	**Resonating Fr in GHz**	**Return-loss in dB**	**BW in GHz**
12	2.11	–28.5	0.01075
11	2.12	–22.7	0.02023
10	2.16	–19.1	0.0382
9	2.18	–22	0.0431
8	2.2	–23	0.0483
7	2.21	–22	0.0381
6	2.22	–25	0.02050
5	2.25	–26	0.02815

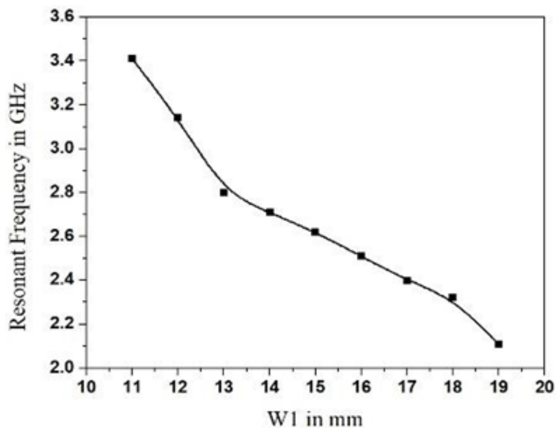

Fig. 3 – Fluctuation of resonant frequency as a function of W_1

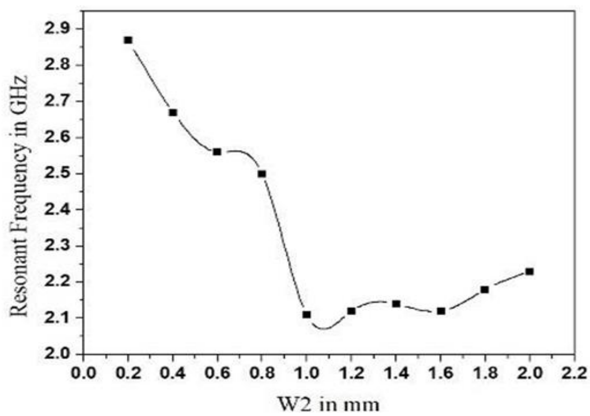

Fig. 4 – Fluctuation of resonant frequency as a function of W_2

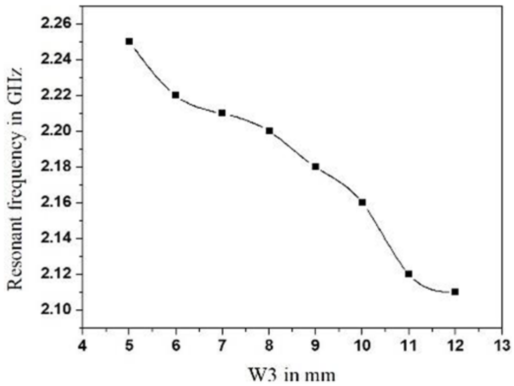

Fig. 5 – Fluctuation of resonant frequency as a function of W_3

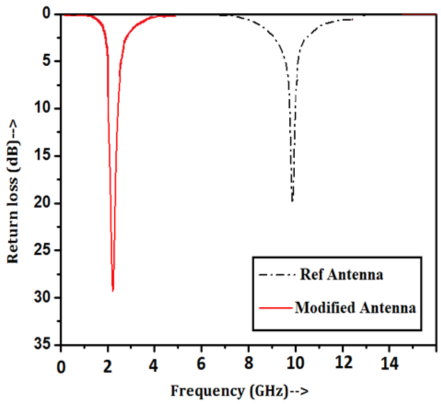

Fig. 6 – Graphical Presentation of Frequency vs Return Loss

3. RESULTS AND COMPACTNESS

The reference antenna's 10 GHz resonance is with a finite ground plane and with the optimal size of the U – shaped slotted ground plane, the final designed antenna resonates at 2.11 GHz. In Fig. 6, a graphical representation of the simulated findings for the reference and suggested antennas is presented. At 2.11 GHz, the antenna's gain was found to be 2.5 dBi and the graph is presented in Fig. 7. The simulated co-pol and cross-pol radiation patterns at 2.11 GHz for the suggested antenna are shown in Fig. 8. The proposed antenna has been estimated to be nearly 96 % more compact than the standard rectangular microstrip antenna resonating at 2.11 GHz.

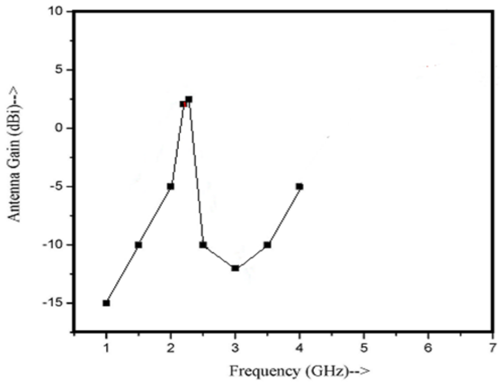

Fig. 7 – Graphical Presentation of Frequency vs Absolute Gain

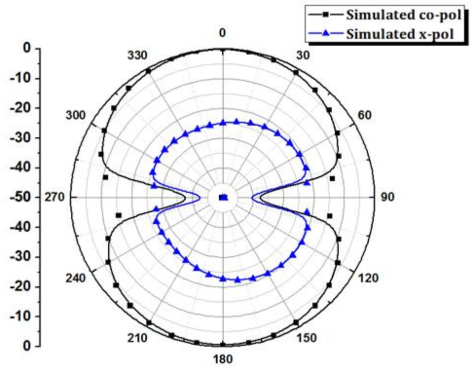

Fig. 8 – Graphical Presentation of Radiation pattern

4. CONCLUSION

The impact of a U-shaped slot at the rectangular ground plane on the resonance frequency, return loss, and bandwidth of a rectangular microstrip patch antenna have been thoroughly studied and analyzed in this literature. To find the U – shaped slot's ideal size for achieving a very low resonant frequency, some parametric analyses have been done. By comparison to the standard rectangular microstrip antenna, the suggested antenna configuration is 96 % more compact and resonates at 2.11 GHz with acceptable gain of 2.5 dBi. This antenna can be used at any portable devices where the space is the main constraint.

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Дослідження та аналіз компактної патч-антени, що використовує площину заземлення з U-слотом

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У цій статті розглядається та вивчається вплив U-подібного слотув площині заземлення прямокутної мікросмужкової антени зі скінченною площиною заземлення. Для створення компактної патч-антени було враховано ідеальний розмір і розміщення U-подібного слота. Розмір ділянки становить 10,6 × 7,8 мм², а розмір загальної прямокутної конструкції антени становить лише 31,8 × 23,4 мм² разом із зміненою задньою площиною землі. Резонансна частота еталонної антени становить 10 ГГц, а після включення U-подібного отвору в заземлену поверхню ця резонансна частота знизилася до 2,1 ГГц. Покращене підсилення антени становить 2,5 дБл. У цій роботі було обговорено дослідження компактності прямокутної мікросмужкової антени та проаналізовано вплив U-подібного слоту на кінцеву площину заземлення на резонансну частоту, зворотні втрати та смугу пропускання. Шляхом налаштування різних параметрів слоту під час параметричного дослідження та вибору найкращого значення розміру та положення слоту була підібрана резонансна частота модифікованої антени, що становила 2,1 ГГц.

Ключові слова: Прямокутна мікрополосна антена, Компактність, U-подібний слот.