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A Novel Compact Differential Microstrip Antenna

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Abstract—A novel compact differential microstrip antenna is presented. Owing to the introduction of slots in the patch and ground plane, the size of the proposed differential antenna is about 0.45 times that of the traditional microstrip antennas. The measured results show that the proposed antenna can work at 2.45 GHz. The gain is about 5.54 dB and the impedance bandwidth about 150 MHz.

1. INTRODUCTION

The past few years have witnessed the rapid development of microstrip antennas owing to their many attractive advantages such as compact size, low profile and easy integration with RF circuit components [1–4]. In comparable to conventional single-ended microstrip antennas, differential microstrip antennas are highly desirable due to their compact and seamless integration with fully differential monolithic microwave integrated circuits (MMICs) and their good radiation performance [5–7]. Accordingly, many efforts have been made to improve the performances of the differential microstrip antennas. For example, a differential-fed patch antenna with wide bandwidth and enhanced radiation performance was described in [8]. In [9], broadband patch antenna with a folded plate pair as a differential feeding scheme was proposed. In [10], a differential dual-band antenna-in-package with multilayer structure was proposed.

However, reducing the size of the differential microstrip antennas still requires further investigation. In this paper, a novel compact differential microstrip antenna with slotted patch and slotted ground plane is presented. Because the surface current path has been lengthened largely, a compact differential microstrip antenna has been successfully designed and implemented. The size of the proposed new antenna is only about 0.45 times that of the traditional microstrip antennas.

2. ANTENNA DESIGN AND PARAMETER ANALYSIS

Geometry of the proposed compact differential microstrip antenna operating at 2.45 GHz is shown in Figure 1. The patch and ground plane are on a substrate with height $h = 1.5\,\text{mm}$, relatively dielectric constant ε_r of 2.65 and loss tangent of 0.0025. The feeding points are placed at 5 mm away from the center of the patch, and the basic parameters of the proposed antenna are as follows: $b = 24.3\,\text{mm}$, $a = 51\,\text{mm}$, $e = 0.5\,\text{mm}$, $g = 19.3\,\text{mm}$, $m = 7.95\,\text{mm}$, $s = 0.4\,\text{mm}$, $u = 21\,\text{mm}$, $n = 8.75\,\text{mm}$, $p = 0.7\,\text{mm}$, $w = 25\,\text{mm}$.

The simulated reflection coefficients of the proposed antenna without slots, with slotted patch, and with slotted patch and slotted ground plane are shown in dotted line, dash line and solid line, respectively. It must be noted that this simulation and all the following simulations are carried out by using ANSOFT HFSS13 simulator. As seen from Figure 2, the working frequency of the antenna with the slotted patch is much lower than that of the antenna without slots. Moreover, the slotted

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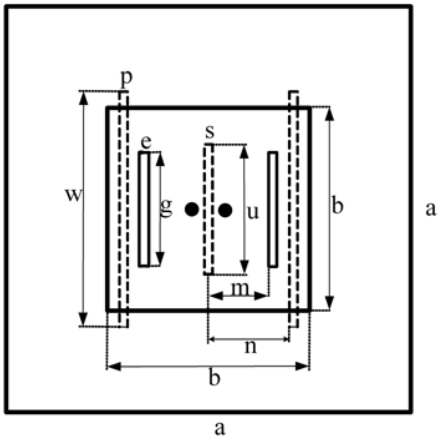


Figure 1. Geometry of the proposed compact differential microstrip antenna.

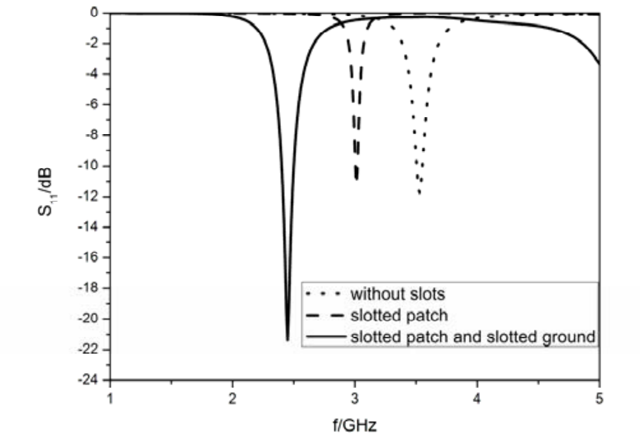


Figure 2. The effects of slots on the resonant frequency of the antenna.

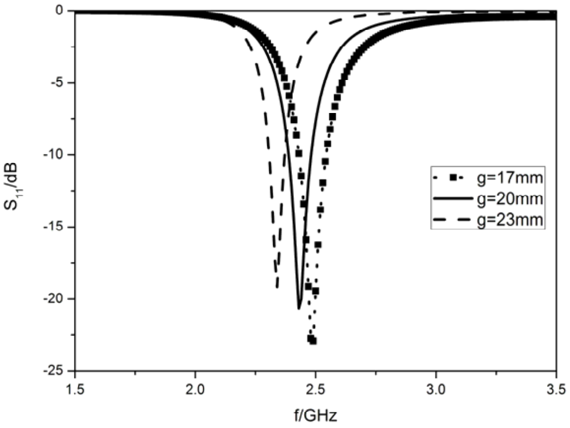


Figure 3. The simulated resonant frequency of the proposed antenna with different lengths (g). ($b = 24.3\,\text{mm}$, $a = 51\,\text{mm}$, $e = 0.5\,\text{mm}$, $m = 7.95\,\text{mm}$, $s = 0.4\,\text{mm}$, $u = 21\,\text{mm}$, $n = 8.75\,\text{mm}$, $p = 0.7\,\text{mm}$, $w = 25\,\text{mm}$).

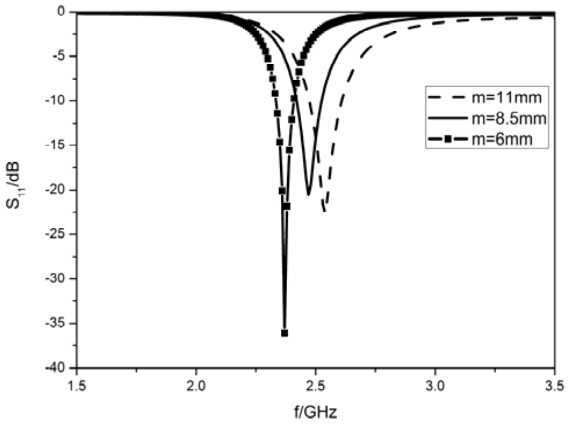


Figure 4. The simulated resonant frequency of the proposed antenna with different distance (m). ($b = 24.3\,\text{mm}$, $a = 51\,\text{mm}$, $e = 0.5\,\text{mm}$, $g = 19.3\,\text{mm}$, $s = 0.4\,\text{mm}$, $u = 21\,\text{mm}$, $n = 8.75\,\text{mm}$, $p = 0.7\,\text{mm}$, $w = 25\,\text{mm}$).

ground plane is another effective technique to reduce the antenna's size. As shown in the graph, the working frequency of the antenna is reduced largely when both the slotted patch and slotted ground are introduced in the design of the differential antenna.

To further investigate the effect of the slotted patch, Figure 3 and Figure 4 compare the simulated return loss of the antenna with different slots on the patch. The simulated operating frequency of the proposed antenna with different lengths (g) and the distance (m) of the adjacent slots are shown in Figure 3 and Figure 4. In general, the larger the length (g) of the slot is, the lower the operating frequency of the antenna is. On the contrary, a smaller distance (m) results in a lower operating frequency.

Figure 5 and Figure 6 also compare the simulated return loss of the antenna with different slots on the ground. As observed from the two graphs, lengths (u) and (w) of the slots also have significant impacts on the operating frequency of the antenna. To be specific, the operating frequency of the antenna decreases with the increase of u and w.

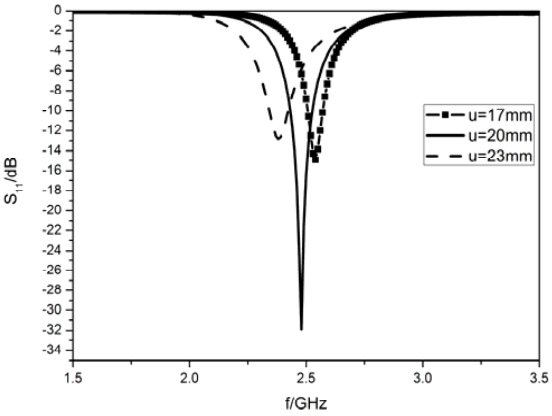


Figure 5. The simulated resonant frequency of the proposed antenna with different lengths (u). ($b = 24.3\,\text{mm}$, $a = 51\,\text{mm}$, $e = 0.5\,\text{mm}$, $g = 19.3\,\text{mm}$, $m = 7.95\,\text{mm}$, $s = 0.4\,\text{mm}$, $n = 8.75\,\text{mm}$, $p = 0.7\,\text{mm}$, $w = 25\,\text{mm}$).

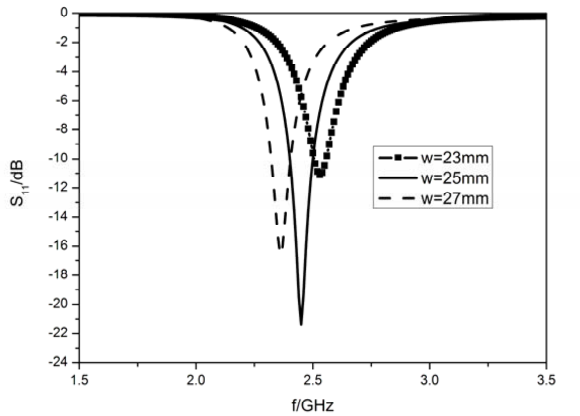
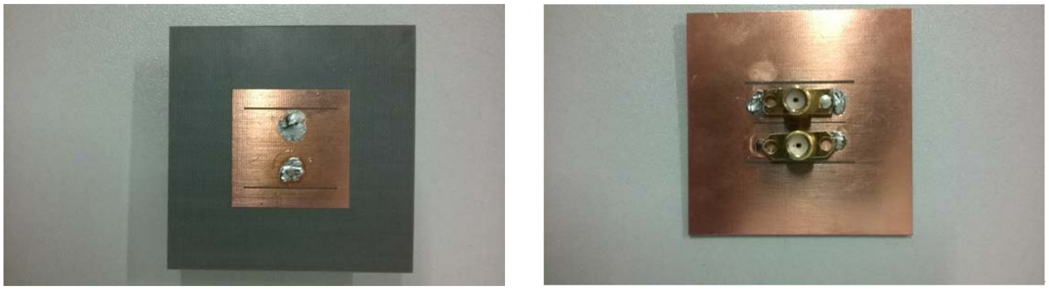


Figure 6. The simulated resonant frequency of the proposed antenna with different lengths (w). ($b = 24.3\,\text{mm}$, $a = 51\,\text{mm}$, $e = 0.5\,\text{mm}$, $g = 19.3\,\text{mm}$, $m = 7.95\,\text{mm}$, $s = 0.4\,\text{mm}$, $u = 21\,\text{mm}$, $n = 8.75\,\text{mm}$, $p = 0.7\,\text{mm}$).



(a) (b)

Figure 7. Photograph of the proposed antenna. (a) Top view. (b) Bottom view.

As can be seen from the above analysis, the slots in the patch and ground plane have significant effects on the resonant frequency, which mainly lengthen the surface current path of the antenna and cause a shift in the resonant frequency. As a result, a compact differential microstrip antenna can be achieved by selecting proper dimensions of slots for a fixed resonant frequency.

3. SIMULATED AND MEASURED RESULTS

The proposed antenna is fabricated on the substrate with height $h = 1.5\,\text{mm}$, relatively dielectric constant ε_r of 2.65 and loss tangent of 0.0025. Figure 7 shows a photograph of the proposed compact differential microstrip antenna.

Due to the lack of facilities to truly measure a differentially-driven antenna, the differentially-driven antenna is conventionally measured by using a balun which can transform the single-ended signal to differential signal. The balun is fabricated on a substrate with height 0.5 mm, relatively dielectric constant 2.65 and loss tangent 0.0025, which consists of a Wilkinson power divider and a 180° phase shifter.

The simulated and measured S_{11} of the proposed compact differential microstrip antenna, together with the balun, are shown in Figure 8. Good agreement can be observed from the graph. As shown in Figure 8, the realized antenna can work at 2.45 GHz. The simulated bandwidth is about 100 MHz while the measured one is about 150 MHz.

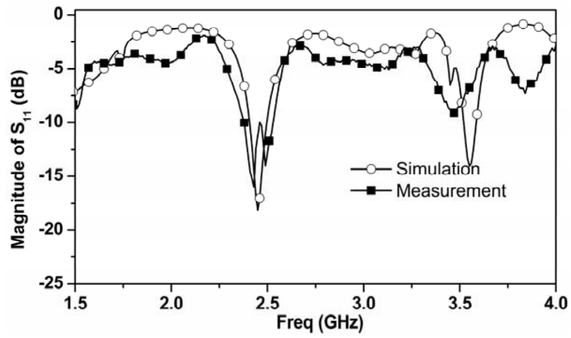


Figure 8. Simulated and measured magnitude of S_{11} of the proposed antenna together with balun.

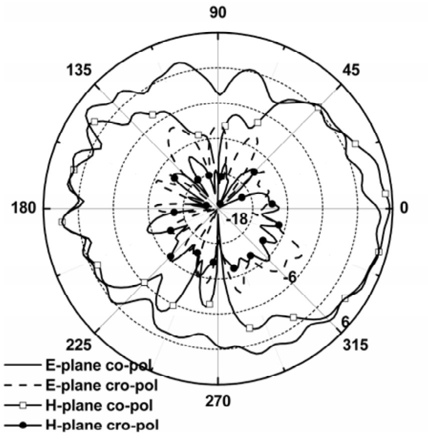


Figure 9. Measured Radiation pattern of the proposed antenna together with balun.

Radiation pattern and gain are measured by antenna measuring system sg24 (satimo corporation) whose noise floor is about −66 dB. The measured radiation pattern at 2.45 GHz is given in Figure 9. The realized antenna has a broadside radiation pattern and low cross polarization. The measured gain of the proposed antenna is about 5.54 dB at 2.45 GHz.

Moreover, the fabricated compact differential microstrip antenna occupies a compact rectangular area of 24.3 mm × 24.3 mm corresponding to $0.087\lambda g^2$ ($0.295\lambda g \times 0.295\lambda g$), where λg is the guided wavelength of a 50 transmission line at the central frequency of 2.45 GHz. As a result, the size of the proposed antenna is only about 45% of that of the traditional microstrip antenna. Also, the size of the referred differential antenna is $0.2015\lambda g^2$ ($0.65\lambda g \times 0.31\lambda g$) in [8], $0.2107\lambda g^2$ ($0.49\lambda g \times 0.43\lambda g$) in [9], $0.1657\lambda g^2$ ($0.4059\lambda g \times 0.4082\lambda g$) in [10], indicating that the proposed antenna possesses a compact size. Thus, the proposed compact differential microstrip antenna is successfully implemented, which can present certain application value in the wireless communication systems.

4. CONCLUSIONS

A novel compact differential microstrip antenna loaded with slots in the patch and ground plane has been described and investigated experimentally in this letter. Based on the differential feeding structure, the antenna can be conveniently integrated with differential RF chips. Loaded with slots in the patch and ground plane, the proposed differential antenna has achieved compact size successfully, whose size is only about 45% of that of traditional microstrip antennas.

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