# CPW-Fed Slot Antenna for Major Wireless Communication Systems

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***Abstract*** ─ In this paper, we present a new co-planar waveguide (CPW)-fed slot antenna for wireless communication systems. The proposed antenna is fabricated on an *FR4* substrate with dielectric constant of 4.4. Configuration of the antenna structure is based on S-shaped structures in both of the radiating stub and ground plane where it operates over a very wide bandwidth and improves the impedance matching. By converting the S-shaped structure at the antenna radiating stub, a new resonance at the lower frequencies is generated, and also by converting the ground plane to the modified S-shaped structure, a good multi-band operation and bandwidth enhancement can be achieved. The measured impedance bandwidth of the proposed antenna for 10 dB return loss is from 1.04 GHz to 1.42 GHz and 1.88 GHz to 2.51 GHz, covering the major wireless communication bands like GPS, MDS/WCS, PCS, WiBro, Bluetooth, HiperLAN, and etc. Simulated and experimental results obtained for this antenna show that the proposed slot antenna has a good isolation and radiation behavior.

***Index Terms*** ─ CPW-fed antenna, wireless communication systems.

## I. INTRODUCTION

Recently, microstrip slot antennas have been largely used in a lot of useful applications, because of their inherent characteristics of low cost, low profile, ease of fabrication, light, weight, conformability and integration with RF devices [1-2]. Operation in two or more discrete bands with an arbitrary separation of bands is desired in many applications, such as global positioning system (GPS), wireless communication service (WCS), high performance local area network (HiperLAN), and so on [3-5].

Dual band or multi frequency operations are a main requirement of this type communication. A single antenna is highly desirable if it can operate at these bands. The antenna should be in the planar form, lightweight and compact, so that it can easily be embedded in the cover of communication devices. To reduce the transmission line length and the radiation losses, a simplified feeding circuit is also an important component [6-7].

In this paper, a novel design of a CPW-fed slot antenna for major wireless communication bands is proposed, which have many advantages such as simple structure of a wide bandwidth and easy integration with active devices. The proposed antenna covers frequency bands of 1.04-1.42 GHz and 1.88-2.51 GHz. The resonant frequency of the antenna can be adjusted by changing the sizes of S-shaped structures. Good return loss and radiation pattern characteristics are obtained in the frequency band of interest.

## II. MICROSTRIP ANTENNA DESIGN

The antenna is fabricated on an FR4 epoxy substrate with dielectric constant $\varepsilon r$=4.4 and loss tangent tan $\delta$=0.02 and thickness h=1.6 mm.

As shown in the Fig. 1, an S-shaped radiator is fed by a 50 CPW transmission line which is terminated with a sub miniature A (SMA) connector for measurement purpose. Since both the antenna and the feeding are implemented on the same plane, only one layer of substrate with single-sided metallization is used, and the manufacturing of the antenna is very easy and extremely low cost. Both the radiating patch and the ground plane are beveled, which results in a smooth transition from one resonant mode to another and ensures good impedance match over a broad frequency range.

The presented slot antenna is fed by a CPW. A CPW is a one type of strip transmission line defined as a planar transmission structure for transmitting microwave signals. It comprises of at least one flat conductive strip of small thickness and conductive ground plates.

A CPW structure consists of a median metallic strip of deposited on the surface of a dielectric substrate slab with two narrow slits ground electrodes running adjacent and parallel to the strip on the same surface.

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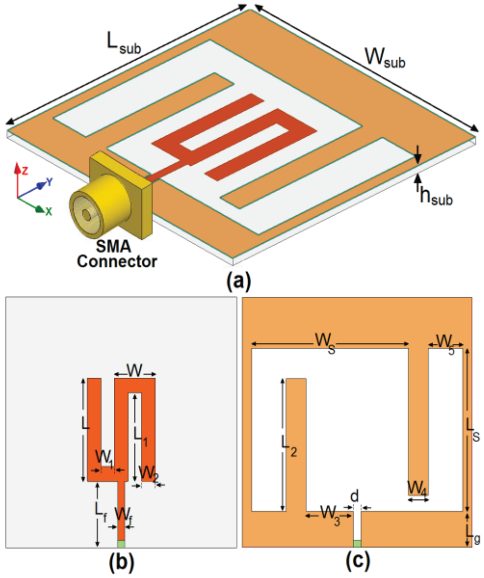


Fig. 1. Geometry of the proposed CPW-fed slot antenna: (a) side view, (b) radiating stub, and (c) ground plane.

As shown in Fig. 1, besides the microstrip line, the CPW is the most frequent use as planar transmission line in RF/microwave integrated circuits. It can be regarded as two coupled slot lines. Therefore, similar properties of a slot line may be expected. The CPW consists of three conductors with the exterior ones used as ground plates. These need not necessarily have same potential. The width of the CPW-feed line is:

$$W_f \leq \frac{120h\pi}{z_0\sqrt{\varepsilon_r}}. \quad (1)$$

For good accuracy of CPW:

$$\frac{d}{h} \leq 0.5mm. \quad (2)$$

As illustrated in Fig. 1, the conductors placed together with distance of d=0.135 mm.

The proposed antenna configuration is shown in Fig. 2. Final values of the antenna design parameters are specified in Table 1.

In this study, to achieve the wideband operation, the radiating stub is converted to S-shaped structure as shown in the figure. By using this structure, a new resonator at 1.25 GHz will be excited whose resonant frequency is higher than the basic structure resonant frequency. Also, in order to achieve another resonance at 2.5 GHz, we used an S-shaped slotted ground plane. Regarding to have S-shaped structures in both of the radiating stub and ground plane, two resonators will be excited, when combined gives a wideband response;

$$W_{sub} = L_{sub} = \frac{c}{2f_L\sqrt{\varepsilon_{eff}}}, \quad (3)$$

$$\varepsilon_{eff} = (\varepsilon_r + 1)/2. \quad (4)$$

In this design, the final length $L_{resonance}$ is set to resonate at $0.25\lambda_{resonance}$:

$$f_{resonance} = \frac{c}{4L\sqrt{(\varepsilon_r + 1)/2}}, \quad (5)$$

where $L_{resonance1}=W_1+0.5L_1$ and $L_{resonance2}=0.25L_2+0.5W_4$ correspond to new resonance frequencies at 1.25 and 2.5 GHz. To investigate the performance of the proposed antenna configuration in terms of achieving wideband operation, a commercially available Ansoft HFSS was used for the required analysis and to obtain the proper geometrical parameters. The simulation processes flow chart is given below in Fig. 3.

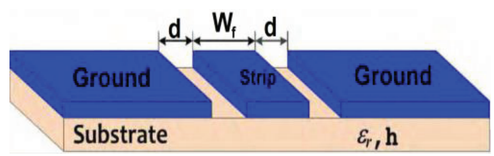


Fig. 2. Coplanar waveguide structure (CPW).

Table 1: Final dimensions of the antenna

| Parameter | $W_{sub}$ | $L_{sub}$ | $h_{sub}$ |
|---|---|---|---|
| Value (mm) | 34 | 34 | 0.8 |
| Parameter | $L_f$ | W | L |
| Value (mm) | 8 | 7.5 | 15 |
| Parameter | $L_2$ | $W_3$ | $L_g$ |
| Value (mm) | 20 | 8.365 | 5 |
| Parameter | $W_S$ | $L_S$ | $W_f$ |
| Value (mm) | 23 | 22 | 1 |
| Parameter | $W_1$ | $L_1$ | $W_2$ |
| Value (mm) | 2 | 12.25 | 2.5 |
| Parameter | $W_4$ | d | $W_5$ |
| Value (mm) | 2 | 1.27 | 3 |

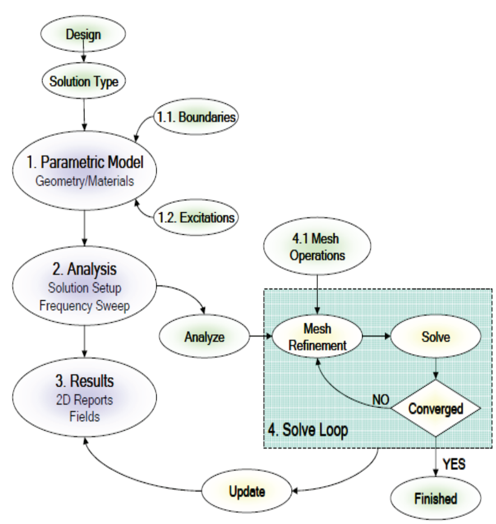


Fig. 3. Flow chart of simulation processes.

## III. RESULTS AND DISCUSSIONS

The proposed CPW-fed slot antenna with various design parameters was constructed, and the numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. Ansoft HFSS simulations are used to optimize the design and agreement between the simulation and measurement results is obtained [9].

The configuration of the various antennas used for simulation studies are shown in Fig. 4. Return loss characteristics for the ordinary CPW-fed slot antenna [Fig. 4 (a)], the antenna with an S-shaped radiating stub [Fig. 4 (b)], the antenna with S-shaped radiating stub and modified ground plane [Fig. 4 (c)], and the proposed slot antenna [Fig. 4 (b)] structures are compared in Fig. 5.

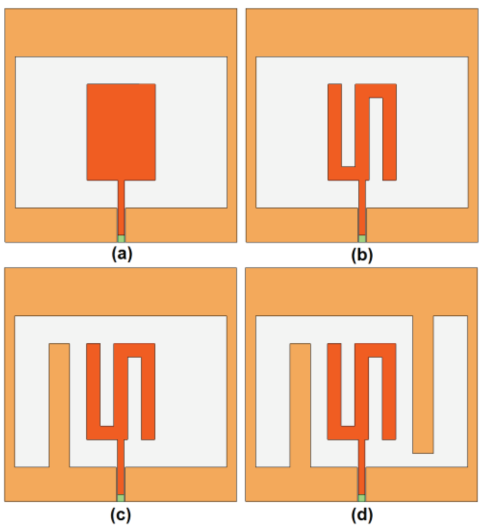


Fig. 4. (a) Ordinary CPW-fed slot antenna, (b) the antenna with an S-shaped radiating stub, (c) the antenna with S-shaped radiating stub and modified ground plane, and (d) the proposed antenna structure.

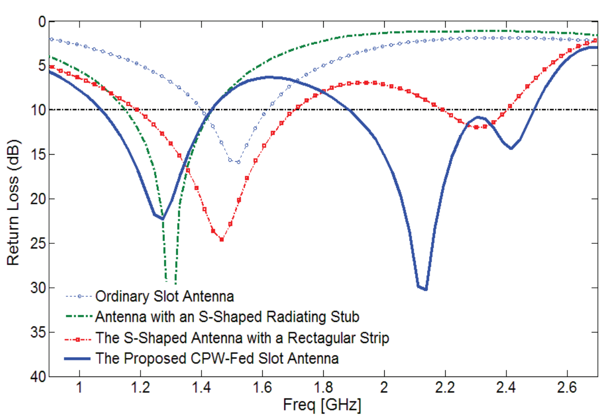


Fig. 5. Simulated return loss characteristics for the various structures shown in Fig. 4.

As shown in Fig. 5, it is observed that the lower frequency bandwidth is affected by using an S-shaped radiating stub and generation of multi-band performance is sensitive to the modified S-shaped ground plane. Also, the input impedance of the proposed antenna on a Smith Chart is shown in Fig. 6.

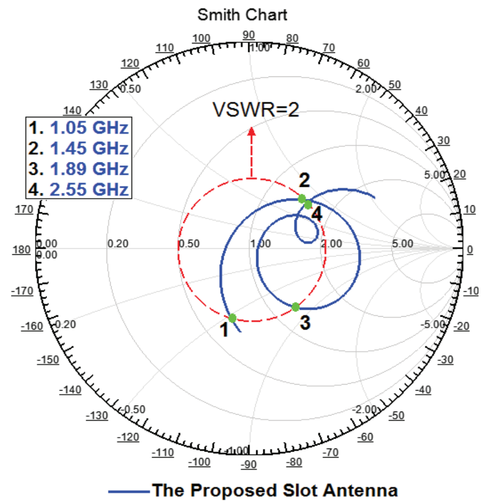


Fig. 6. Simulated input impedance of the proposed antenna on a Smith Chart.

In order to know the phenomenon behind this multi-band performance, the simulated current distributions for the presented antenna at 1.25, 2.15 and 2.4 GHz are presented in Fig. 7. It can be observed in Fig. 7 (a), at the lower frequency (2.1 GHz) the current concentrated on the edges of the interior and exterior of the S-shaped radiating stub. Therefore, the antenna impedance changes at this frequency due to the resonant properties of the S-shaped structure [6].

Another important design parameter of this structure is the modified ground plane structure. Figures 7 (b) and (c) present the simulated current distributions in the ground plane of the proposed antenna at 2.15 and 2.4 GHz (upper frequencies), respectively. As seen, at the upper resonance frequencies, the current flows are more dominant around of the modified S-shaped ground plane.

The proposed antenna with final design was built and tested. The below Fig. 8 shows the antenna fabrication setup.

The VSWR characteristic of the antenna was measured using the HP 8720ES network analyzer in an anechoic chamber. The radiation patterns have been measured inside an anechoic chamber using a double-ridged horn antenna as a reference antenna placed at a distance of 2 m. Also, two-antenna technique using an Agilent E4440A spectrum analyzer and a double-ridged horn antenna as a reference antenna placed at a distance of 2 m is used to measure the radiation gain in the z axis direction (x-z plane). Measurement set-up of the proposed antenna for the VSWR, antenna gain and radiation pattern characteristics are shown in Fig. 9.

The measured and simulated return loss characteristics for the proposed antenna were shown in Fig. 10. The fabricated antenna has a frequency band from 1.04 GHz to 1.42 GHz and 1.88 GHz to 2.51 GHz.

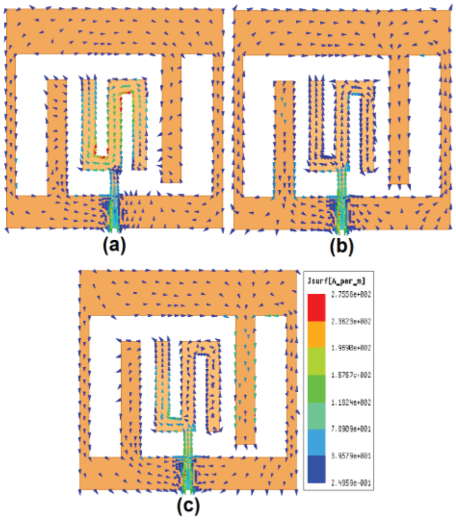


Fig. 7. Simulated surface current distributions for the proposed antenna at: (a) 1.25 GHz, (b) 2.15 GHz, and (c) 2.4 GHz.

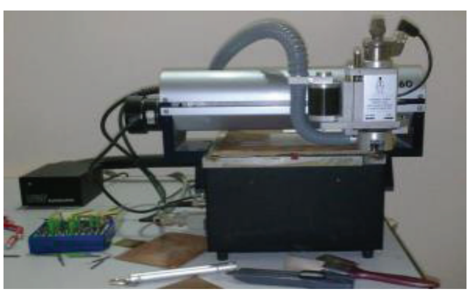

Fig. 8. Fabrication setup.

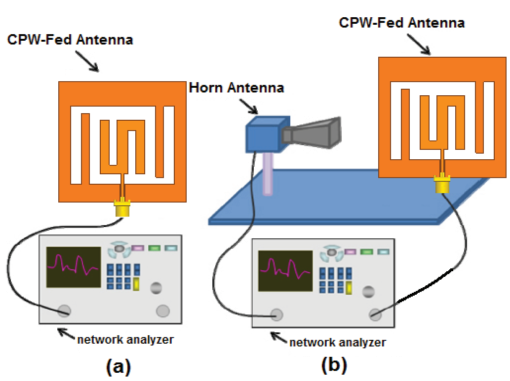


Fig. 9. Measurement set-up of the proposed antenna: (a) return loss, and (b) antenna gain and radiation patterns.

Figure 11 shows the measured radiation patterns including the co-polarization and cross-polarization in the *H*-plane (*x-z* plane) and *E*-plane (*y-z* plane). The main purpose of the radiation patterns is to demonstrate that the antenna actually radiates over a wide frequency band. It can be seen that the radiation patterns in *x-z* plane are nearly omnidirectional for the three frequencies. With the increase of frequency, the radiation patterns become worse because of the increasing effects of the cross-polarization [10-13]. Figure 12 shows the measured maximum gain of the proposed antenna for operation frequency bands.

The radiation intensity corresponding to the isotropic ally radiated power is equal to the power accepted by the antenna divided by 4π. This can be expressed as:

$$G = \frac{4\pi U(\varphi,\theta)}{P_{in}}. \quad (6)$$

It is assumed that the antenna is receiving a signal in the direction of maximum gain. It is also common for the gain to be expressed in decibels and referenced to an isotropic source (G=1), as shown:

$$G(dBi) = 10\,Log\,(G/1). \quad (7)$$

As illustrated the antenna has sufficient and acceptable gain level in these bands [14-15].

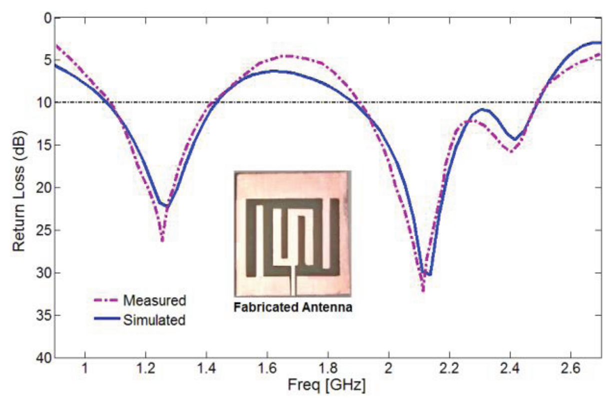


Fig. 10. Measured and simulated return loss characteristics for the proposed antenna.

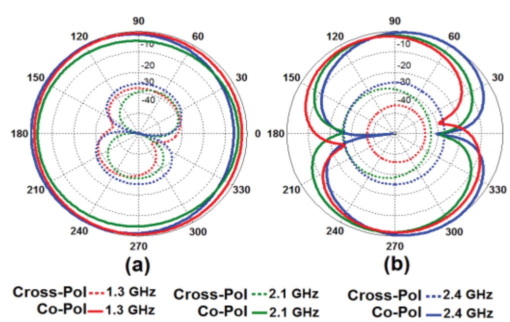


Fig. 11. Measured radiation patterns of the proposed antenna: (a) H-plane, and (b) E-plane.

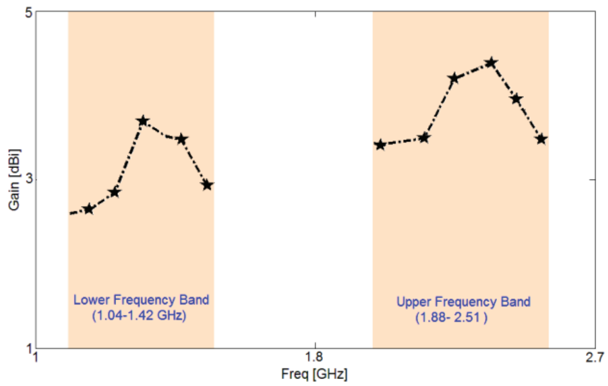


Fig. 12. Measured maximum gain for the proposed slot antenna.

## IV. CONCLUSION

A novel dual-band CPW-fed slot antenna for major wireless communication bands is presented in this paper. The antenna configuration consist of modified S-shaped radiating patch and ground plane. The proposed antenna can operate from 1.04 GHz to 1.42 GHz and 1.88 GHz to 2.51 GHz. The designed antenna has a small size of 34×34 $mm^2$. The proposed antenna configuration is simple and easy to fabricate.

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