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Effects of Modified Ground Structure on a CPW-fed Patch Antenna

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Abstract

This paper presents a study of a coplanar waveguide (CPW-fed) antenna using a Modified Ground Structure (MGS). The antennas studied are relatively small in size (17 x 20) mm^2 and was designed on a low-cost FR-4 substrate. The presented antenna models shows improvements in the impedance bandwidth, the center frequency and operating bands with the stages of modification being introduced in the ground structure. The designed antennas were simulated using Ansoft HFSS, a FEM based simulator and antenna's characteristics such as Reflection coefficient, Center frequency, Operating frequency bands, Impedance bandwidth, and VSWR are reported in this paper.

Keywords: *CPW-fed, FR-4 substrate, MGS, S11, Impedance bandwidth, VSWR*

1. Introduction

With the increase in demand for wireless communication, an antenna designed with CPW structure has became more applicable in today's era of multi-band application. CPW structure allows etching of patch and ground of an antenna on the same side of a substrate thereby reduces the complexity and makes fabrication easier. Most of the CPW-fed monopole antennas were proposed because of attractive characteristics such as low cost, light weight, compact size and multi-resonance modes. In [1-4], different techniques of designing dual-band WLAN antenna have been proposed. In [1], Ali et al. have presented a dual-band antenna for WLAN band applications. In [5], Deshmukh et al. have shown a technique for bandwidth enhancement of microstrip antennas using λ/4 resonant slots. In [6], some methods for designing compact, low-profile and broadband microstrip antennas were discussed. The various feed structures such as the probe, the microstrip, and the coplanar waveguide (CPW) were shown in [7-16].

In this paper, a relatively small CPW-fed antenna of dimension (17 x 20) mm^2 has been studied with some stages of modification being introduced in the ground structures and was designed on a low-cost FR-4 substrate. The antenna models show good improvements related to frequency of operation, operating frequency bands and impedance bandwidth with the introduction of ground levels and resulted in a dual frequency operation. The antenna's performance was simulated using Ansoft HFSS.

2. Basic Antenna Model

The basic CPW-fed antenna model and its geometry are shown in Figure 1 and made to work as reference antenna for further study in this research. The parameters for the antenna shown in Figure 1 are tabulated in Table 1, and were optimized using Ansoft HFSS software. In this section, antenna characteristics such as reflection coefficient, center frequency, VSWR, operating frequency bands and impedance bandwidths are simulated for Figure 1 by varying the feed and step width with a constant length of 4 and 2.43 mm respectively, and obtained results are tabulated in Table 2.

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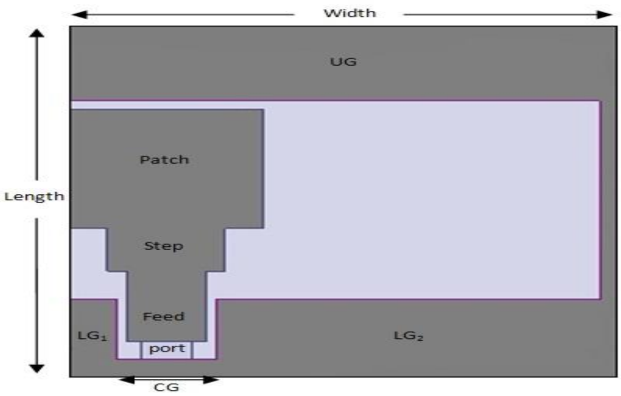


Figure 1. Geometry of the Basic Antenna Model

Table 1. Parameters for the Antennas Shown in Figure 1

Parameter			Size(mm)		
			Width	Length	Height
Substrate			17.00	20.00	1.00
Patch			6.00	6.78	0.02
Step			3.67	2.43	0.02
Feed			2.50	4.00	0.02
Port (rectangular sheet)			1.55	1.04	0.00
Grounds	Upper ground	UG	17.00	4.25	0.02
	Lower ground	LG_1	1.45	4.40	0.02
		LG_2	12.45	4.40	0.02
	Connecting ground	CG	3.10	0.96	0.02

Table 2. Simulated Results for Figure 1

Step Width (mm)	Feed Width (mm)	S11 (dB)	Center freq. (GHz)	Freq. Band at -10dB (GHz)	Band-width at -10dB (GHz)	VSWR
3.67	2.7	-9.6707	1.002	0	0	1.9782
3.67	2.5	-9.0955	1.002	0	0	2.0813
4.67	2.7	-9.3760	1.002	0	0	2.0293
6.00	2.7	-9.5953	1.002	0	0	1.9909

3. Modification of Grounds

This section presents the stages of modification being introduced in the ground layer of the antenna shown in Fig. 1 and the effects and consequences of using Modified Ground Structure (MGS) is also described. The study begins with a reference antenna (Antenna I) and finally to an Antenna IV. The reference antenna (Antenna I) is further studied here by introducing some MGSs with an optimum feed size (2.5 x 4 x 0.02) and step size (3.67 x 2.43 x 0.02). The parameters considered for Antenna I-IV are tabulated in Table 3.

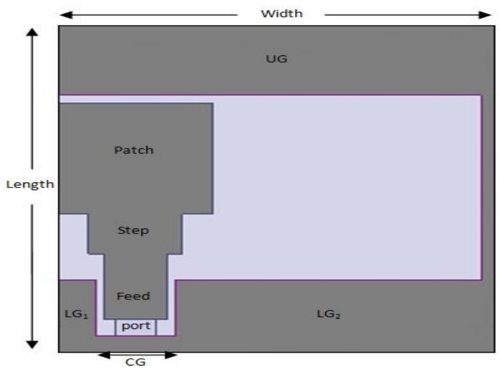
Table 3. Parameters for the Antenna I-IV

Parameter			Size(mm)		
			Width	Length	Height
Substrate			17.00	20.00	1.00
Patch			6.00	6.78	0.02
Step			3.67	2.43	0.02
Feed			2.50	4.00	0.02
Lumped Port (rectangular sheet)			1.55	1.04	0.00
Grounds	Upper ground	UG	17.00	4.25	0.02
	Lower ground	LG_1	1.45	4.40	0.02
		LG_2	12.45	4.40	0.02
		LG_3	8.375	3.60	0.02
		LG_4	2.625	1.60	0.02
		LG_5	1.3125	1.00	0.02
	Connecting ground	CG	3.10	0.96	0.02

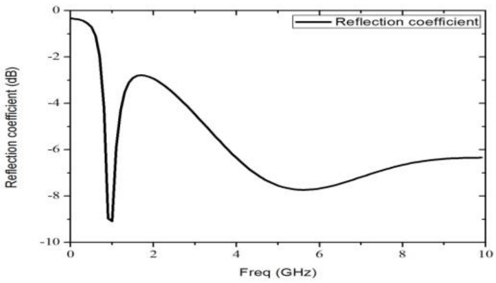
The effects and consequences of modifying the ground of the antenna are explained in below:

3.1. Effect of MGS (LG_{1-2} & UG)

The geometry of Antenna I is shown in Fig. 2(a) and the obtained reflection coefficient plot is shown in the Fig. 2(b). It is seen that the Antenna I generates a resonant frequency of 1.002 GHz with a reflection coefficient ≤ -5dB (-9.0955dB).



(a)

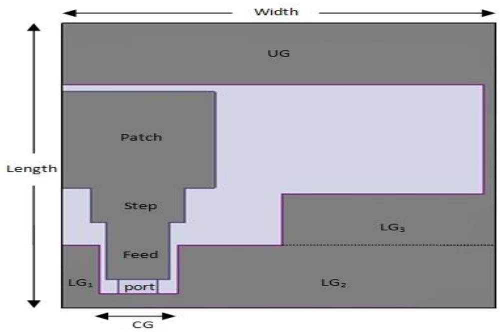


(b)

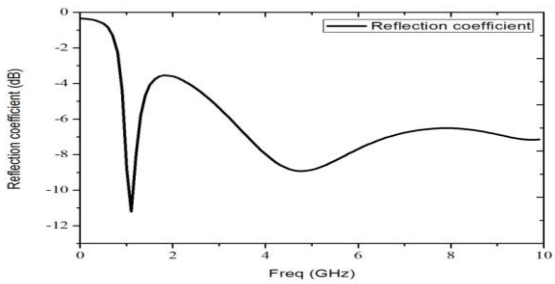
Figure 2. (a) Geometry of Antenna I, and (b) Simulated Reflection-Coefficient

3.2. Effect of LG_{1-3} & UG

The Antenna II and its geometry are shown in Figure 3(a) and the obtained reflection coefficient plot is shown in the Figure 3(b). It is seen that by adding LG_3 to Antenna I, resonant frequency increases from 1.002 GHz to 1.102 GHz resulting in a reflection coefficient ≤ -10dB (-11.2018dB).



(a)

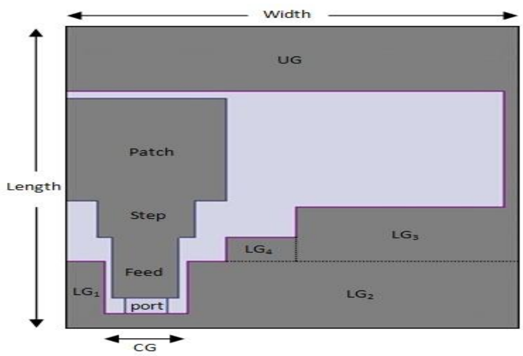


(b)

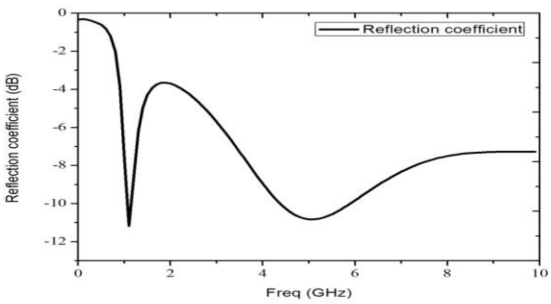
Figure 3. (a) Geometry of Antenna II, and (b) Simulated Reflection-Coefficients

3.2. Effect of LG_{1-4} & UG

The Antenna III and its geometry are shown in Figure 4(a). By adding ground LG_4 to Antenna II, the resulted Antenna III starts exciting with resonant frequencies 1.102 GHz and 5.102 GHz with reflection coefficients $\leq$ -10dB *i.e.*, -11.1761dB and -10.8226dB respectively.



(a)

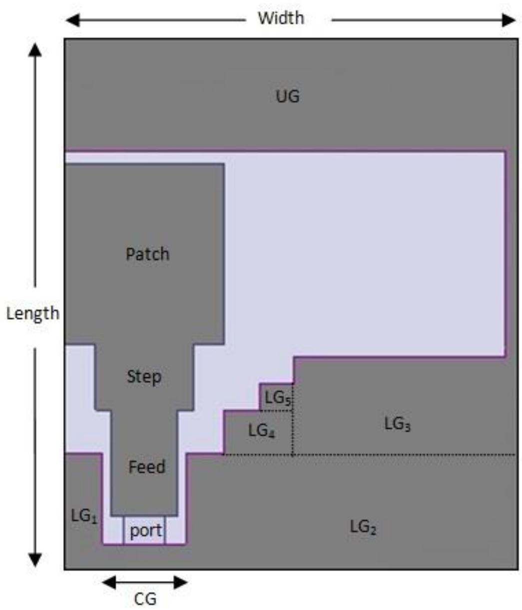


(b)

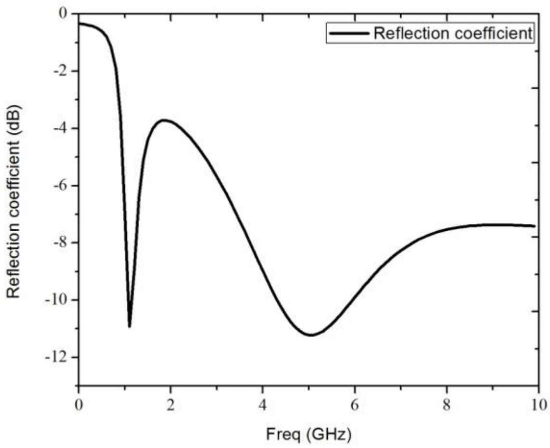
Figure 4. (a) Geometry of Antenna III, and (b) Simulated Reflection-Coefficients

3.3. Effect of $LG_{1\text{-}5}$ & UG

The geometry of Antenna IV is shown in Figure 5 (a) and the obtained simulated reflection coefficient is plotted in Figure 5(b). The obtained resonant frequencies are 1.102 and 5.002 GHz with reflection coefficient of -10.9230 and -11.2176dB respectively.



(a)



(b)

Figure 5. (a) Geometry of Antenna IV, and (b) Simulated Reflection-Coefficients

4. Results and Analysis

The CPW-fed antennas presented and studied in this paper have a dimension of (17 x 20) mm^2 and was designed on a FR-4 substrate with dielectric constant 4.4 and thickness 1mm. The simulated results of the antennas plotted in Figure 2-5, such as Reflection coefficient (S11 in dB), VSWR, operating frequency bands, and center frequency and impedance bandwidth are tabulated in Table IV. The Figure 6 describes the comparative analysis of the antennas that was shown in Figure 2-5.

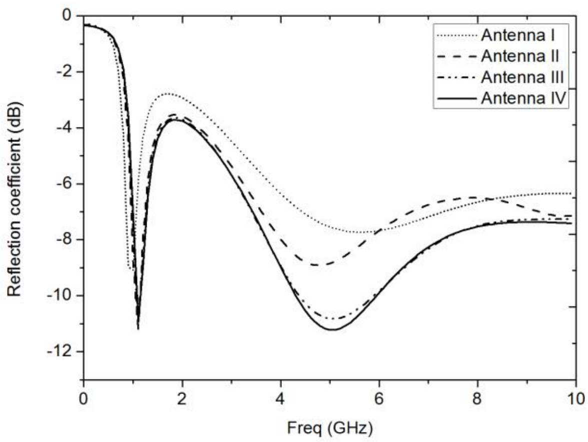


Figure 6. Simulated Reflection-Coefficients for Antenna I-IV

Table 5. Simulated Results for the Antennas Shown in Figure 2-5.

Antenna	S11 (dB)	Center freq. (GHz)	Freq. Band at -10dB (GHz)	Impedance Bandwidth at -10dB (GHz)	VSWR
Antenna I	-9.0955	1.002	0	0	2.0813
Antenna II	-11.2018	1.102	1.10-1.13	0.03	1.7600
Antenna III	-11.1761	1.102	1.06-1.14	0.08	1.7631
	-10.8226	5.102	4.37-5.89	1.52	1.8076
Antenna IV	-10.9230	1.102	1.07-1.14	0.07	1.7947
	-11.2176	5.002	4.30-5.94	1.64	1.7581

From the tabulated results presented in Table IV, it is observed that, with the introduction and modification of grounds, the antenna performances such as operating frequency band, impedance bandwidth and center frequency shows good improvements and results in decrease of reflection coefficient to ≤ -10dB.

5. Conclusion

A small CPW-fed antenna is studied by introducing some modified ground structures. The antenna is realized with distinct operating bands and frequency. The overall CPW-fed technique thus enables the realization of a dual-band antenna maintaining the dimensions being considered in this research. The CPW-fed antenna has various advantages such as compactness, light weight, low cost, wide bandwidth and integrable with small device which makes an antenna well-suited for wireless applications.

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