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Evolution Process of a Broadband Coplanar-Waveguide-fed Monopole Antenna for Wireless Customer Premises Equipment

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Abstract

In this paper a design process of a broadband printed monopole antenna using stepped cut at four corners (CSFC) technique is proposed. The CSFC is a technique that four corners a patch (rectangular/square) of planar monopole antennas are cut in order to enhance the impedance bandwidth. The technique can be used to design any different types of planar monopole antenna in specific frequency ranges. Therefore, to become more acquaintance with the CSFC technique an evolution process of single band to broadband antenna is represented. However, the proposed antenna is designed for wireless indoor customer premises equipment (CPE) using the coplanar waveguide (CPW) feeding technique. Moreover, the antenna is simulated using CST software and also fabricated and tested so as to validate the results. The simulated and measured -10 dB reflection bandwidth is 104% (850MHz to 2.7GHz) to cover GSM (900 and 1800MHz), WiFi (2.4 GHz) and LTE (2.6GHz) applications. High efficiency and gain as well as omnidirectional and quasi-omnidirectional of radiation pattern at lower and upper frequencies have been achieved.

Keywords: *coplanar waveguide, monopole antenna, customer premesis equipment*

1. Introduction

Given the fact that antenna is a vital part in current, emerging and future wireless communication systems. Also, the demand for antennas with wide impedance bandwidth for use in multifunctional wireless communication systems has spurred many researchers to focus on multiband and wideband antennas. The CPW-fed monopole antenna have attracted so much research interests, due to its low-profile, light weight, ease of fabrication, cheap cost, ease of integration with other kinds of microwave integrated circuits (MICs) and capability of being deployed for both linear and circular polarizations. Therefore, several methods have been reported based on the CPW-fed monopole ante One common method is to etching different shaped slots on the radiating patch or ground such as; inverted U-shaped slot [1, 2], W-shaped slot etched on the radiation patch and the ground plane [3], inverted V-shaped slot with folded ends embedded on the radiating patch and two symmetrical rectangular slots on the ground plane [4], a circular slot is etched on the radiating patch and resonant cell within the CPW line [5], two T-shaped slots being cut from the patch [6], and π-shape and V-shape slots on the radiating element [7]. Other main approaches for this application use resonant parasitic patches and slot [8] and split ring resonator [9].

Wireless broadband is a technology that provides computer networking access or high-speed wireless Internet access over a wide area. The CPE is a fundamental part of any wireless broadband access (WBA). There are many reasons for utilizing the CPE in WBA; this includes superior coverage, significant performance boost, reduced service turn-up costs, fixed demarcation point and reduced helpdesk costs [10].

2. The Evolution Process of the Broadband Antenna

The proposed technique due to the final shape of radiated patch is called “Stepped Cut at Four Corners (SCFC)”. As the name implies, four corners of the radiated element

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(rectangular/square shape) of a planar monopole antenna are created in the form of stepped line in order to obtain the desired operating frequency band [11]. to become more familiar with SCFC technique, the design process of planar monopole broadband antenna with frequency range from 0.85GHz to 2.7GHz is designed and simulated. According to the SCFC technique the dimensions of main patch are belongs to the lower frequency, therefore the single band antenna is designed at 0.85GHz. Also, the dimensions patch of the upper frequency is specified in order to cut the corners, which leads to create a dual band antenna to cover the operating frequencies at 850MHz and 2.7GHZ. To design the triple band antenna, given the CSFC technique, two steps should be created in four corners of the main patch. Therefore, the dimensions of the third patch; between the patches of lower frequency and upper frequency e.g. 1.5GHZ, are calculated. Consequently, by increasing the number of steps at the corners a multiband antenna resonating at multiple frequencies is obtained. As discuss in [11], *n-1* patches can be created between the P_{FL} and P_{HF}, which create *n* steps at four corners of the main patch. Hence, to full coverage of the expected frequency bandwidth, the number of steps is increased in order to design the broadband antenna. Figure 1 depicted the evolution process of the proposed antenna from single band to broadband.

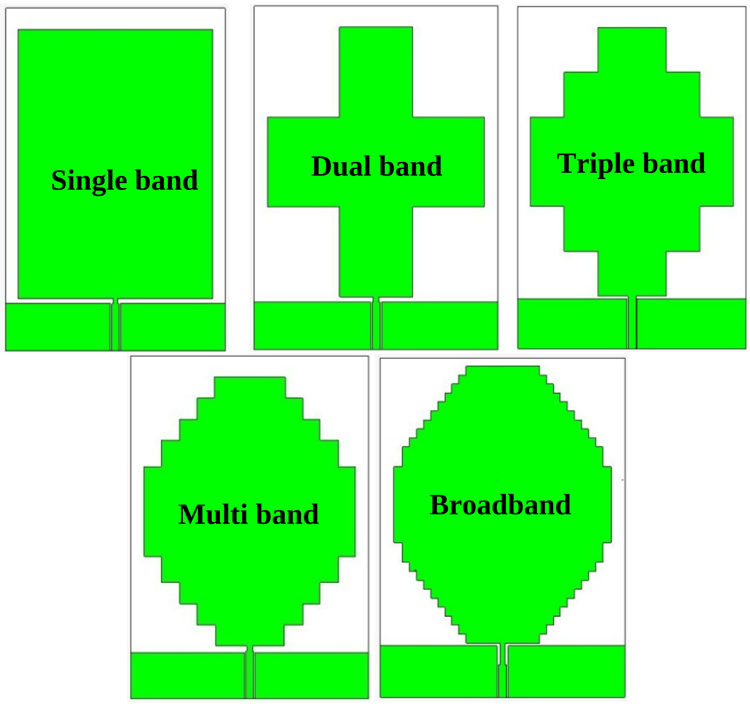


Figure 1. Evolution Process of Single Band to Broadband Antenna

Figure 2 shows the simulated S11 of the single band to broadband antenna. As it can be seen that, the operating frequency of 850MHz is covered using the single band antenna based on the return loss better than 10dB. Also, the dual band antenna can cover frequency bands of 850MHZ and 2.7GHz. Moreover, as expected three operating frequencies for triple antenna, it covers 850MHz, 1.5GHz and 2.7GHz. In addition, by increasing the number of steps and overlapping property of resonance frequencies, the multiband antenna is covered the frequency ranges of 0.85-1.7GHz and 2.3-2.7GHz. Finally, the broadband antenna as a target of the evolution process can cover the entire frequency band of 850MHz to 2.7GHZ. Meanwhile, the broadband antenna is described in more details in the next section.

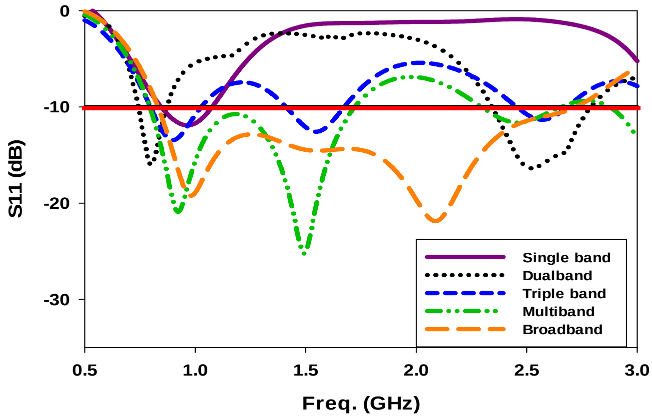
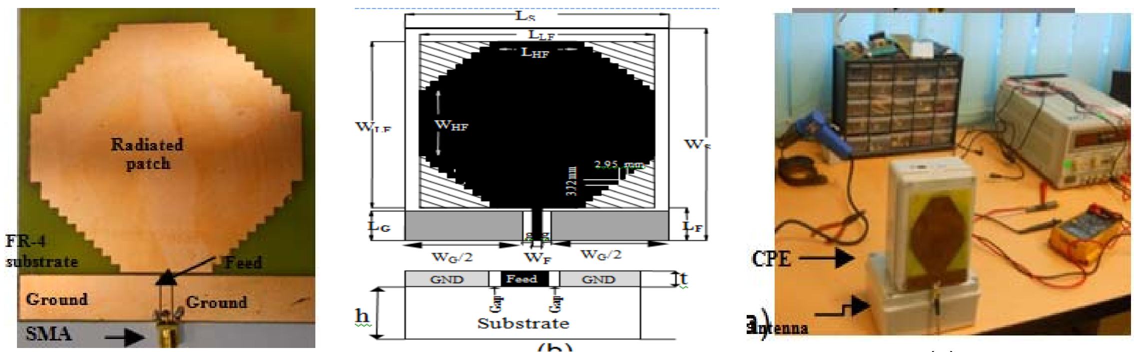


Figure 2. Simulated S11 of the Proposed Antennas from Single Band to Broadband

3. Broadband Planar Monopole Antenna

The Photograph of the manufactured prototype and the geometric details as well as the CPE device of the broadband CPW-fed monopole antenna using CSFC technique have been shown in Figure 3. The design and simulation of the proposed antenna has been carried out using CST microwave studio software. The antenna is etched on a FR-4 dielectric substrate with relative permittivity εr = 4.3, thickness h=1.6mm, Length Ls=90 mm and width W_S=125mm. Both the radiating patch and the ground plane are located on the same side of the dielectric substrate due to the structure being CPW-fed and its made of copper material with s thickness t=0.035mm and conductivity σ=5.96e7s/m. The ground plane length and width are L_G=18.5mm and W_G=86mm respectively. To achieve 50Ω output impedance matching with the sub miniature version A (SMA) connector, a transmission line feed with width W_F=3 mm and length L_F=20mm and coupling gap g=0.4mm was used.



(a) (b) (c)

Figure 3. (a) Photograph of fabricated prototype (b) geometric details of Broadband antenna (c) CPE with the attached antenna

In order to validate the simulated results, the prototype has been fabricated and tested by Rohde and Schwarz ZVL network analyzer. Figure 4 shows a comparison between the simulated and measured return loss. The results exhibited that, the proposed antenna has a capable of operating at a broad frequency range of 850MHz and 2.7GHz based on The operating frequency range can cover GSM (0.9 and 1.8GHz), WiFi (2.4GHz), and LTE (2.6GHz) applications the |S11|<-10dB.

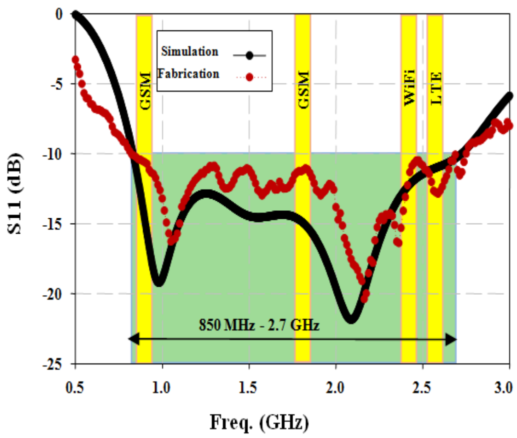


Figure 4. Simulated and Measured S11 for Proposed Antenna

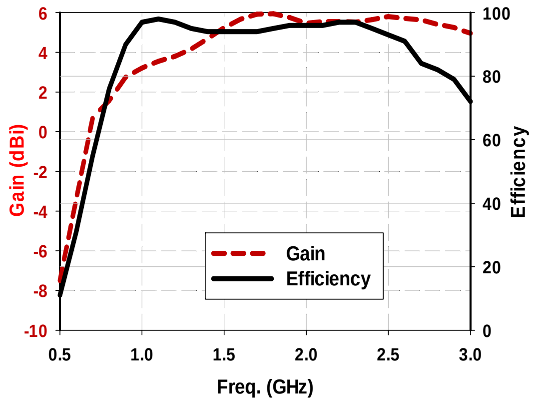


Figure 5. Simulated Realize Gains and Radiation Efficiency

Simulated realized gain and radiation efficiency of the proposed antenna are shown in Figure 5. It is observed that, the radiation efficiency of more than 90% and gains of 3-5.9dBi at the desired direction ($\theta = 0^\circ$ and $\varphi = 90^\circ$) over the expected bandwidth have been achieved. Figure 6 illustrates the normalized measured radiation pattern in the x-z (H) plane and y-z (E) plane at 900MHz, 1.8GHz, 2.4GHz and 2.6GHz. The H-plane evident that omnidirectional radiation patterns are obtained at 0.9 and 1.8GHz while quasi-omnidirectional radiation patterns are achieved at 2.4 and 2.6GHz.

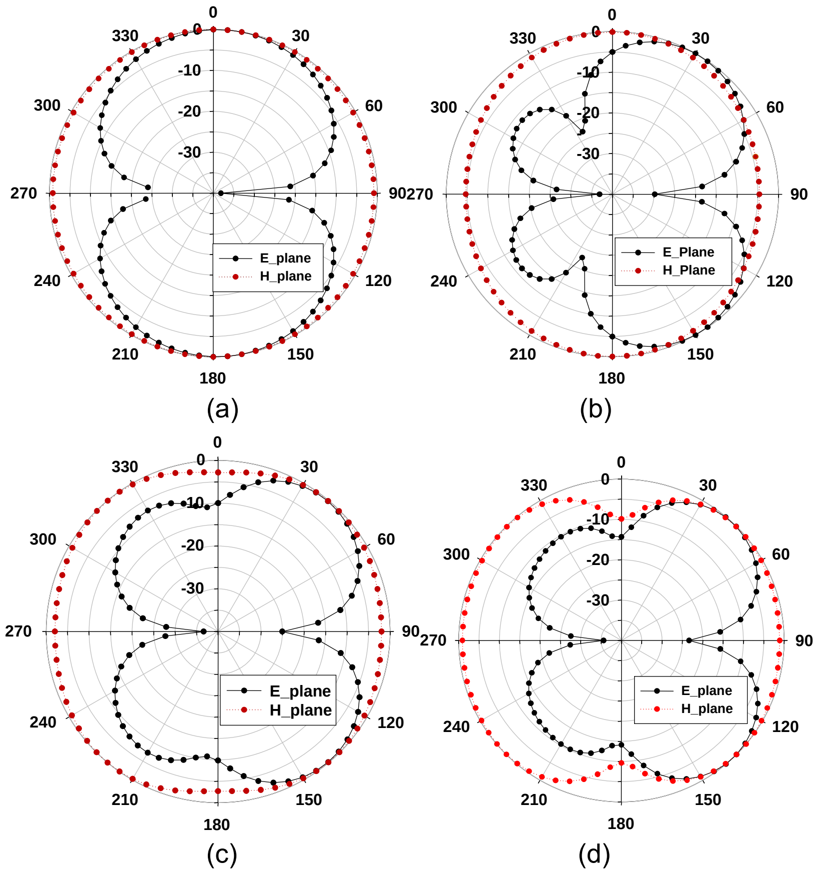


Figure 6. Measured Normalized 2D Radiation Pattern at (a) 900MHz (b) 1.8GHz (c) 2.4GHz and (d) 2.6GHz

4. Conclusion

In this article a new technique is introduced to enhance the bandwidth of planar monopole antennas based on the CPW-fed method. In order to more familiar with the CSFC, an evolution process of design a broadband CPW-fed monopole antenna suitable for wireless CPE application is presented. The process of design includes five stages, which begin with the single band to the broadband antenna. The CST software is employed throughout the stages and in order to validate the simulated data the broadband antenna as an instant is manufactured and measured. The expected bandwidth covers the GSM (0.9 and 1.8GHz), WiFi (2.4GHz) and LTE (2.6GHz) applications based on the return less more than 10dB. The broadband antenna has demonstrated good performance in terms of reflection coefficient, gain and efficiency as well as radiation pattern. The simulated gains and radiation efficiency were obtained as 3-5.9dBi and more than 90%, respectively. Also omnidirectional patterns at lower frequencies and nearly omnidirectional patterns at upper frequencies are achieved. It is noted that, the SCFC technique has many advantageous features including capability to design different types of the planar monopole antennas, simplicity of the structure, can be used to design an MIMO antenna, etc.

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