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# Design of a compact planar wide band antenna family

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ABSTRACT

A new family of compact planar wide band antennas is proposed. These simple and planar antennas have stable omnidirectional patterns and flat gain in the whole of bandwidth. Five types of these antennas are designed and simulated to clarify the ability of these introduced antenna family. Also, one of these antennas is fabricated and tested. The simulation and the measurement results are in good agreement. The measurement results show that this antenna works between 1.91 and 5.25 GHz (93.3% bandwidth) and it has a very compact dimensions. Also, the antenna analysis results show that the antenna center frequency and bandwidth can easily controlled by changing the scale factor and section factor, respectively. Finally, the antennas comparison results with the references verify the capability and power of them.

## 1. Introduction

Daily wideband and ultra wideband systems have many applications in the communication systems such as microwave radar imaging [1], high data rate systems [2] and positioning systems [3]. The antenna is a critically part of these systems with significant effects in the system performance. In addition to the antenna input impedance, omnidirectional and stable radiation pattern, low group delay, flat gain, high efficiency and low profile are other important antenna specifications in the wide bandwidth applications. Also, the agility in modern systems is very important and small size of antenna can improve this capability. Moreover this fact is known that the instability in radiation pattern or high deviation in gain increase the bit error rate of the system and the channel capacity is decreased, consequently [4,5].

The wideband antennas have been proposed in different antenna categories such as slot, monopole, dipole, Yagi, LPDA and Vivaldi [6–9]. Among these different wideband antenna categories, the wideband dipole based antennas have good radiation pattern and gain stability, as well as high efficiency respect to other ones. One of the famous wideband dipole based antenna is biconical antenna [10]. The biconical antenna was proposed in [11] which has omnidirectional and stable radiation pattern, but it needs 3D structure and is very bulky. In [12], a low profile type of the biconical antenna has been proposed for miniaturization purpose. The magneto-electric dipole antenna is another type of wideband dipole based antenna which has a low profile [13,14]. However, the radiation pattern of this antenna is directional. Moreover, the antenna 3D configuration can cause some problems in the system integrity.

The planar wideband dipole antenna is another attractive type of dipole antenna. The simple structure, reasonable gain, easy fabrication, low volume and weight and easy integration to other parts of microwave systems are important positive characteristic of these antennas [7,15–18]. These antennas need a balun matching which causes size enhancement. Moreover, the radiation pattern stability is another drawback of these antennas which has been solved in some literatures such as [19–20].

A half bowtie antenna with embedded balun has been presented in [20] as a planar wideband dipole antenna. Although this presented antenna has a very small size, but its radiation pattern in the end of bandwidth is not omnidirectional. In [21], the taegeuk dipole antenna with an ultra-wideband impedance bandwidth has been proposed, but its radiation pattern is not stable and the antenna has a large size. An ultra-compact end-loaded dipole antenna presented in [22] that have a small size. This antenna has a good stable radiation pattern and wide bandwidth, but its 3D balun limit the antenna integrability into the communication systems. A printed dipole antenna with a very stable omnidirectional radiation pattern has been designed in [17], but the antenna size is large. Moreover, a simple idea for wideband and dual-band planar dipole antenna has been proposed in [23]. In this work we propose a new family of wideband planar dipole antennas, named as

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planar two section antennas. These antennas show wide impedance bandwidth and have a stable radiation pattern (omnidirectional pattern) and flat gain (maximum gain deviation < 4 dB) in the whole operation bandwidth. Since the antenna balun structure is designed by a planar tapered line transmission from coaxial cable to antenna, the antenna has a compact size compared with the presented antennas in other references such as [21,22,25,26]. Moreover, the antenna cross polarization is low. Also, the antenna design procedure is very simple and the antenna attribute such as the center frequency and bandwidth can be simply controlled. Five different members of this antenna family are proposed in this paper. The square antenna discussed in Section 2, is introduced for the basic idea development and discussion. Moreover, this antenna is fabricated and tested to verify the simulation results. The antenna works from 1.91 to 5.25 GHz (93.3% bandwidth) with a very compact size compared with the literatures [6,10,16–19,23–25]. Some other members of this proposed antenna family are discussed in Section 3 which follow the basic idea presented in Section 2 for the square antenna. The antenna analysis is discussed in Section 4, also. In this section, the antenna design procedure is analyzed to control the center frequency and bandwidth. Moreover the antenna effective surface and its gain flatness are analyzed. Finally, the proposed square antenna as a member of this antenna family is compared with the wideband antennas introduced in the literatures to clarify the ability and capability of this proposed antenna family.

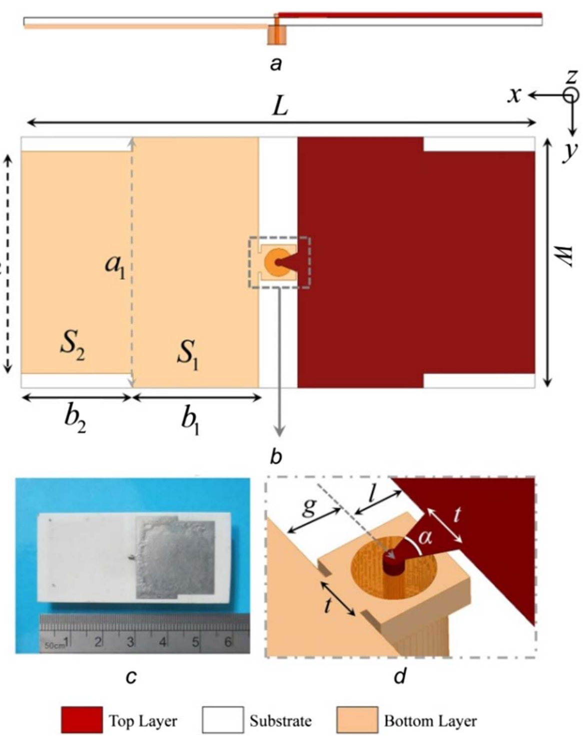


**Fig. 1.** (a) One memeber side view of the propsoed antenna family, the square antenna (b) The antenna prototype with the design parameters (c) Fabricated antenna on 20 mil RO4003 Substrate (d) Antenna feed structure and parameters.

## 2. Square antenna design

### 2.1. Basic idea

The proposed antenna configuration is shown in Fig. 1. The antenna arms composed of two square sections printed on the top and bottom of Rogers 4003 substrate with thickness of 20 mil, relative permittivity of 3.55, and loss tangent of 0.0027.

To clarify the basic idea behind of the proposed antenna, we start from a simple one section square dipole antenna with two arms printed on the both substrate sides. The antenna arm dimensions are considered as 24.8 × 12.4 $mm^2$. The antenna current distributions in two frequencies are shown in Fig. 2. Notice that the all full wave simulation results reported in this paper are extracted by using Ansoft HFSS software. The current distributions depict that the antenna has a resonance at $f_1$ (3.87 GHz) where the length of effective current path is approximately $\lambda_{g1}/4$ similar to the conventional dipole antenna and

$$\lambda_{g1} = \frac{c}{f_1\sqrt{\varepsilon_{eff}}} \tag{1}$$

$$\varepsilon_{eff} \approx \frac{\varepsilon_r + 1}{2} \tag{2}$$

Moreover, the current distribution at $f_2$ (5.25 GHz) shows that the antenna can have a resonance in another frequency, but the impedance matching is false. Notice that the dashed arrows show the real current path, while the solid arrows depict the resultant current path that is approximately about $\lambda_{g2}/4$. Notice that the real current vectors can be decomposed into vertical and horizontal components where the horizontal components cancel each other fields and radiations in farfield.

This antenna structure can work better in bandwidth and size if a second square section is added to the antenna structure as shown in Fig. 1b. The second section geometry is considered similar with the first section except in size, where their dimensions are proportional with a section factor, $d$ as

$$\frac{a_2}{a_1} = \frac{b_2}{b_1} = d \tag{3}$$

where $a_1$, $b_1$, $a_2$ and $b_2$ are the first and second sections dimensions which their values are reported in Table 1. Here we consider $d = 0.89$.

The simulated $|S_{11}|$ and input impedance of this two sections square antenna with ideal port feeding is depicted in Fig. 3(a). Also, the two sections antenna current distributions are shown in Fig. 4. As it presented in these figures, compared with the one section antenna, the first resonance mode $f_1$ (3.87 GHz) is moved to a lower frequency (2.37 GHz), as well as the second resonance mode $f_2$ (5.25 GHz) where appeared at 4.66 GHz. Also one zero in the image part of the antenna

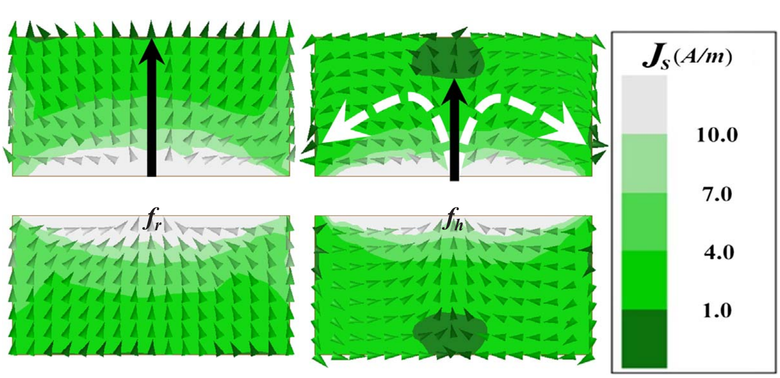


**Fig. 2.** The current distribution and resultant current path for one section square antenna in resonance ($f_1$ = 3.87 GHz) and out of band ($f_2$ = 5.25 GHz) frequencies.