

Design of a Wide Dual-Band Coplanar Probe Feed Antenna for WLANs Applications

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Abstract

This paper presents a new design to obtain wide dual-band operation from a coplanar probe feed antenna loaded with two shorted walls. The lower band of proposed antenna has a 10 dB bandwidth of 611 MHz (24.18%) around the center frequency 2527MHz, and the upper band has a bandwidth of 1255 MHz (27.88%) around the center frequency 4501MHz. The obtained bandwidths cover WLANs operations on all bands. The bandwidth of the first operating frequency covers ISM band (2400-2483.5) MHz, which is required by IEEE 802.11b, g and Bluetooth standards, and the bandwidth of the second operating frequency covers U-NII1 (5150-5350) MHz band, which is required by IEEE 802.11a and HiperLAN2 standards, and also covers U-NII2 (5470-5725) MHz and U-NII3/ISM (5725-5825) MHz bands, which are required by IEEE 802.11a standard. A three dimensional finite-difference time-domain (3-D FDTD) method is employed to analyze the proposed structure and find its performance. The simulated results are compared with the experimental results.

KEYWORDS: microstrip antenna, dual-band antenna, wideband antenna, wireless local area network (WLAN), finite-difference time-domain (FDTD), conventional perfect match layer (CPML).

I. INTRODUCTION

Some applications such as satellite links, wireless local networks (WLAN), cellular telephones and global positioning system (GPS) require wideband dual-frequency antennas, and microstrip patch antennas can be used to satisfy these requirements due to their low profile structure, light weight, ease of integration with microwave integrated circuits (MICs), and capability of producing dual frequency operations [1,2].

Various methods have been used to achieve dual frequency operation such as excitation of orthogonal modes [3], using slots in the patch [4,5], loading the patch with shorting pins [6,7], using stacked patch [8,9] and using planar antennas with special geometries to create several resonance paths [10]. Using these methods achieves very narrow bandwidth, 0.5% - 1.5% (SWR=2), so it is necessary to use additional techniques to improve it.

In this paper, a new design of a broadband dual-frequency antenna with coplanar probe feed is presented. A two shorting walls between the patch and the ground plane are existed to control the two resonant frequencies. A full-wave method of a three dimensional finite- difference time-domain (3-D FDTD) method is employed to analyze the proposed structure and find its performance. The advantage of using the FDTD method is that the structures with complex geometry can be analyzed in this numerical technique. The

obtained bandwidths cover WLANs operations on all bands. The first band covers ISM (2400-2483.5MHz) band, and the second band covers U-NII1 (5150-5350) MHz, U-NII2 (5470-5725) MHz, and U-NII3/ISM (5725-5825) MHz bands [11].

In Section 2 the details of the design considerations of the proposed antenna are described. The simulation and experimental results of the antennas performance are presented in Section 3 and Section 4. The conclusion is presented in section 5.

II. ANTENNA GEOMETRY

Fig. 1 shows the proposed antenna, where the radiating patch has dimensions of $(19 \times 40) \text{ mm}^2$. The ground plane is L-shaped to facilitate the use of coplanar probe feed. In this design, the horizontal portion of L-shaped ground plane has dimensions of $(50 \times 60) \text{ mm}^2$ and the vertical portion of L-shaped ground plane has a height of 10 mm constituting an air-layer substrate to this antenna. The vertical portion of the ground plane is shifted a distance 2 mm from edge of the horizontal portion of the ground plane. A two shorted walls with a width of 2 mm are connected between the patch and the horizontal portion of the L-shaped ground plane and placed at distance d from the vertical portion of ground plane.



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The inner edges of two shorted walls are separated by a distance 36 mm.

The distance of two shorted walls from the patch edge d is varied to have a variable frequency ratio of the two resonant frequencies.

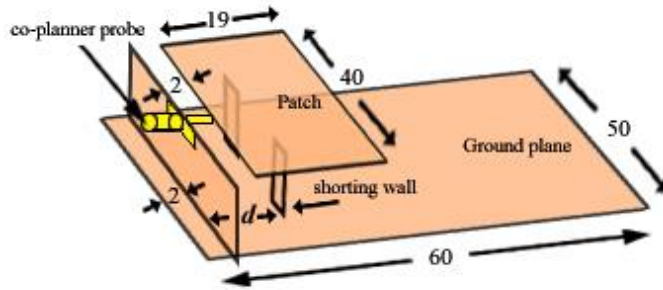


Fig. 1: Proposed configuration for dual-band coplanar probe feed antenna.

The 3-D FDTD method is used for the simulation of the complete structure of the antenna. The FDTD problem space is composed of cells with $\Delta x = 0.5\text{mm}$, $\Delta y = 0.5\text{mm}$ and $\Delta z = 2\text{mm}$ which are selected to be smaller than $(1/20)$ wavelength of maximum frequency (6.5GHz) in order to ensure the accuracy of the computed results [12,13]. These cell sizes make the volume of object to be $(120\Delta x, 100\Delta y \text{ and } 5\Delta z)$. The boundaries are terminated by 8 cells conventional perfect match layers (CPML) and 10 cells air gap is left between the object in the problem space and CPML boundaries. The calculated time step is $\Delta t = 1.045\text{ psec}$ and the simulation is performed for 2200 time steps.

III. RESULTS AND DISCUSSION

The simulation is performed with different values of d , and Fig. 2 shows the simulated return losses for different values of d . The two resonant frequencies (f_{r1} and f_{r2}) and the frequency ratio (f_{r2}/f_{r1}) variations against d variations are shown in Fig. 3, and the corresponding antenna performance is listed in Table I.

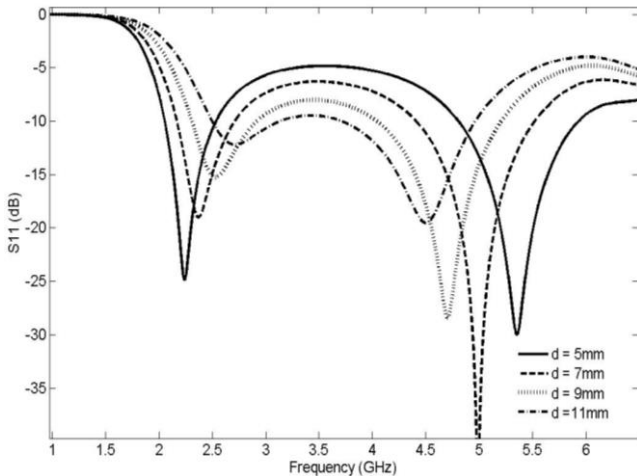


Fig. 2: Calculated Return losses for different value of d .

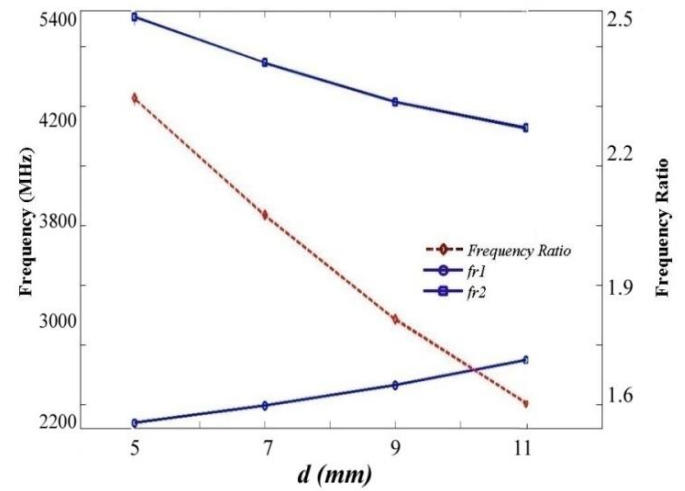


Fig. 3: Resonant frequencies f_{r1} and f_{r2} and frequency ratio (f_{r2}/f_{r1}) against d .

TABLE I
PERFORMANCE OF THE ANTENNA FOR
DIFFERENT VALUE OF d

d mm	f_{r1} MHz	BW_1 MHz, %	f_{r2} MHz	BW_2 MHz, %	(f_2/f_1)
5	2239	482, 21.53	5354	1127, 21.05	2.39
7	2371	545, 22.99	5002	1111, 22.21	2.11
9	2527	611, 24.18	4701	1164, 24.76	1.86
11	2719	639, 23.50	4501	1255, 27.88	1.66

From the above results, it is clear that the increasing in the distance d causes the lower frequency f_{r1} to increase and the higher frequency f_{r2} to decrease, so that the frequency ratio decreased. It is also clear that, the 10 dB bandwidth at the first resonant frequency reaches 24.18% and 27.88% at the second resonant frequency. These are large values of bandwidth compared with the other structures.

From Table I, it is shown that, by setting $d = 5\text{ mm}$ the lower frequency of the proposed design has a bandwidth of 482 MHz (2054-2536) MHz, and the upper frequency has a bandwidth of 1127 MHz (4804-5931) MHz. These obtained bandwidths cover WLAN operations in all bands. The bandwidth of the first operating frequency covers ISM band (2400-2483.5) MHz, which is required by IEEE 802.11b,g and Bluetooth standards, and the bandwidth of the second operating frequency covers U-NII1 (5150-5350) MHz band, which is required by IEEE 802.11a and HiperLAN2 standards, and also covers U-NII2 (5470-5725) MHz and U-NII3/ISM (5725-5825) MHz bands, which are required by IEEE 802.11a standard.

The proposed antenna with $d=5\text{ mm}$ has been constructed and shown in Fig. 4. The measured and simulated return losses of designed antenna are shown in Fig. 5. There is a good agreement between simulated and measured results.

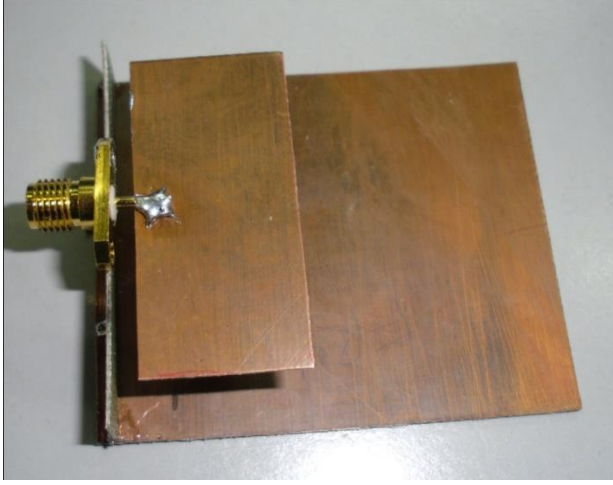


Fig. 4: A photograph of co-planner microstrip antenna.

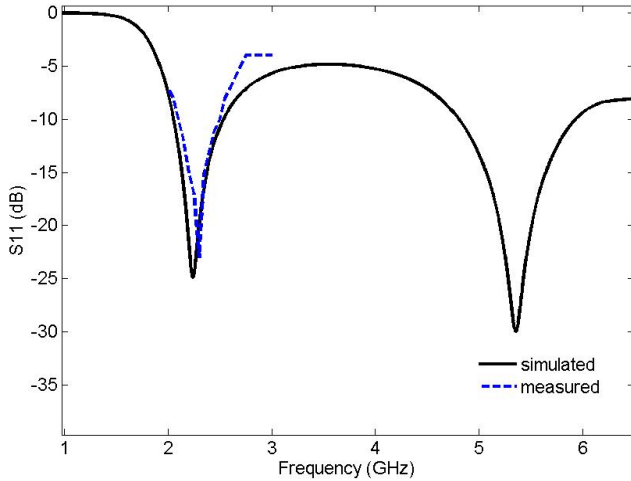


Fig. 5: Measured (2-3GHz) and simulated return losses for $d = 5\text{ mm}$.

Note: It is worth to mention that the measurements that have been done on the fabricated antenna are considered in the frequency range (2-3) GHz. This is due to the practical limit of the RF generator available at our lab.

IV. FAR-FIELDS CALCULATIONS

With the FDTD technique, the direct evaluation of the far field calls for an excessively large computational domain, which is not practical. Instead, the far-zone electromagnetic fields are computed from the near-field FDTD data through a near-field to far-field transformation technique [14].

The directivity patterns are calculated in the xy , xz , and yz plane cuts at 2.45 GHz and 5.6 GHz for $d=5\text{ mm}$. These

patterns are plotted in Fig. 6, Fig. 7, and Fig. 8, respectively. A three dimensional patterns for the two resonant frequencies are calculated and plotted in Fig. 9.

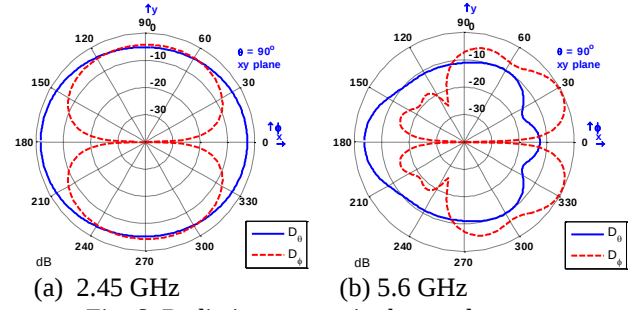


Fig. 6: Radiation pattern in the xy plane cut.

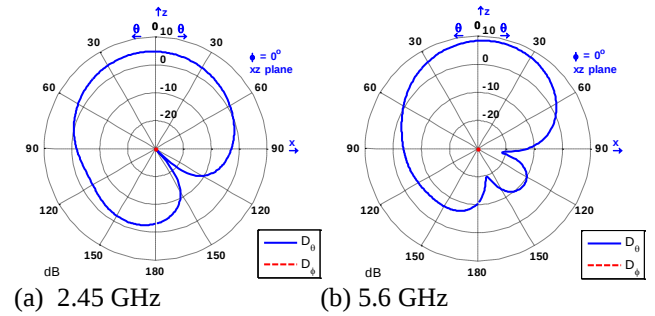


Fig. 7: Radiation pattern in the xz plane cut.

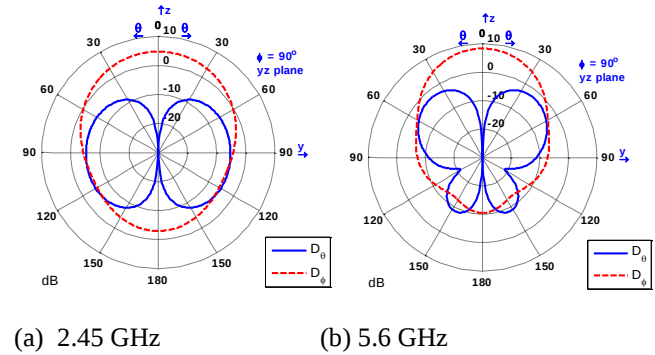


Fig. 8: Radiation pattern in the yz plane cut.

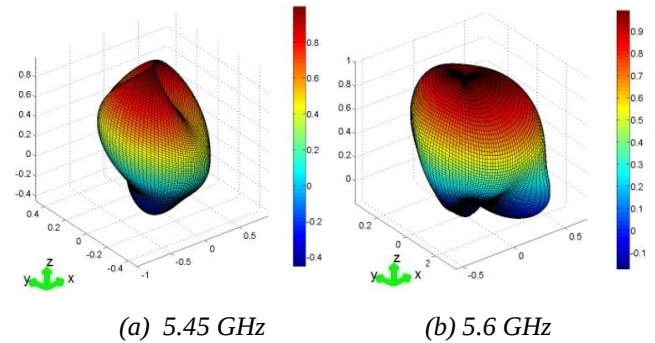


Fig. 9: Three dimensional radiation patterns of the proposed antenna.

V. CONCLUSION

A new coplanar probe feed antenna is proposed in this paper to obtain a wide-band dual-band operation. The proposed antenna is loaded by two shorting walls existed between patch and ground plane. The distance of two shorted walls from the patches edge d is varied to obtain the effect of them on the two resonant frequencies and their bandwidths. The proposed structure is analyzed by the 3D-FDTD method and the calculated results of the proposed antenna agree well with experimental results. The first band of proposed antenna has a 10 dB bandwidth of 24.18% at the center frequency 2527MHz, and the second band has a bandwidth of 27.88% at the center frequency 4501MHz. The first band covers ISM (2400-2483.5MHz) band, and the second band covers U-NII1 (5150-5350) MHz, U-NII2 (5470-5725) MHz, and U-NII3/ISM (5725-5825) MHz bands.

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