A Coplanar Capacitively Coupled Probe Fed Microstrip Antenna for Wireless Applications

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1. Introduction

Microstrip antennas are versatile candidates for the modern broadband wireless applications because of their numerous advantages [1]. Yet most conventional geometries typically have narrow bandwidth, which limits their use in several applications. However it has been shown by several researchers that the bandwidth of microstrip antenna can be significantly improved by altering its basic configuration. These alterations include, increasing the height (or thickness) of the substrate, cutting slots in the basic shapes, changing the shape of the geometry, or using multi-layer techniques [2]. Bandwidth enhancement can also be achieved by modifying the feed networks (elements) such as meandered probe or changing the probe to L-shape or by reactive loading [3]. Many of these have relatively complex assembly, which in some cases is contrary to the fundamental attraction of microstrip antennas.

This group has reported a simple modification to the feed arrangement by which the impedance bandwidth of the antenna (S_{11}<-10dB) could be enhanced to 50% [4]. It is well known that the bandwidth enhancement can be achieved by increasing the overall height of the dielectric medium. However this introduces the large probe inductance, which could be cancelled out by the capacitive feed strip placed parallel to one of the radiating edges of the patch. Although suspended configurations are simple to implement and offer numerous advantages, the use of air gap increases the height/volume of the antenna which is undesired in several (compact) applications. In this work we propose a design that uses small air gap for the similar antenna designs reported earlier. The antenna developed here is suitable for various wireless applications like ISM (2.4-2.5 GHz), PCS cellular spectrum widely licensed across the US at 1.9 GHz, broadband wireless commercial service delivery in US (2.3GHz) etc.

The basic design of the antenna is presented in the next section. Its design starts with the selection of center frequency as the design approach can be easily scaled to any frequency of interest [4]. Simulation studies to determine the dimensions of the key design parameters and the slot are presented in Section 3. Experimental validations are presented in the later part of Section 3. Conclusions of this study are given in Section 4.

2. Antenna Geometry

The basic geometry of the antenna is shown in Figure 1. The configuration is basically a suspended microstrip antenna in which radiating patch and the feed strip are etched on the substrate of thickness "*h*" mm. A long pin SMA connector is used to connect the feed strip which couples the energy to a radiating patch by capacitive means. The length and width of the patch are designed for 2GHz operation as suggested in [4, 5]. The radiator patch is loaded with a vertical slot to make the antenna resonant for lower frequencies and for proper matching with the input impedance of the antenna.

The antenna was designed to operate with a center frequency of 2GHz. Radiator patch dimensions can be calculated from standard design expressions after making necessary corrections for the suspended dielectric [1]. These corrections incorporate the total height above the ground (*g*

+h) and effective dielectric constant of the suspended microstrip [6]. It has been shown that the impedance bandwidth of the antenna may be maximized by using the design expression [4]

$$g \cong 0.16\lambda_0 - h\sqrt{\varepsilon_r}\ . \tag{1}$$

Where g is the height of the substrate above the ground, and h and ε_r are the thickness and dielectric constant of the substrate. However it should be noted that the equation (1) enables us to predict only initial value and the final value may be optimized with the simulation tools like IE3D.

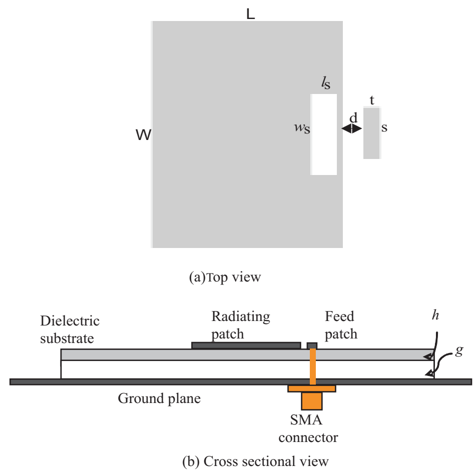


Figure 1: Geometry of a Proposed Patch Antenna with a Capacitive Feed.

3. Simulation Studies And Experimental Results

In this study we use an Arlon substrate (dielectric constant=2.5, tan δ =0.0017 and thickness = 1.56mm) placed above the ground plane at a height of g=8.5mm. The optimized geometry parameters of the antenna with slot are listed in Table 1. All these geometrical parameters (Table 1) are optimized with the IE3D which is a method of moments (MoM) based electromagnetic (EM) software by the approach explained in [4]. Parametric studies were conducted on key design parameters (d, t and s) to optimize the antenna's impedance bandwidth as suggested in [4, 5]. Although the antenna was designed and tested for S_{11}<-6dB (VSWR 3.01:1), it can be used as a dual resonant antenna for S_{11}<-10dB (VSWR 2.0:1) applications.

It may be noted that according to (1) the calculated air gap is 21.3mm and the optimum air gap reported in [4] is 19.2mm. In this work we have made an effort to reduce the air gap significantly. It may also be noted that reducing the air gap in suspended configurations results in the shift of operating band on higher side. This is basically due to increase in the effective dielectric constant of the composite air-dielectric medium. To avoid the frequency shift, a slot has been introduced. It may be recalled that, cutting a slot inside the radiator patch ensures the wide bandwidth [3]. The slot dimensions are optimized using IE3D and are discussed in the following paragraphs.

The three parameters need to be considered while optimizing the slot dimensions are, slot length, slot width, and its placement within the radiator patch. First, slot position was optimized by arbitrarily choosing the slot dimensions (slot length=6mm and slot width=32mm). Slot position was varied from 20mm to 23mm. The return loss characteristics are plotted in Figure 2 (a). From these plots it may be noted that the optimum position is found out to be at 22.5mm away from the radiating patch center.

In next step, placing a slot at 22.5mm away from the center of patch and keeping slot width (w_s) =32mm constant, slot length was optimized. Slot length was varied from 5mm to 7mm. It can be noticed from Figure 2 (b) that, slot length below 5mm, -6dB bandwidth splits and beyond 7mm, the length of the radiator patch restricts the slot position. Finally, slot width was varied from 33mm to 37mm. For this, slot position and slot length are chosen as 22.5mm and 7mm (optimized) respectively. Return loss characteristics for different values of slot width values are shown in Figure 2 (c). The optimum slot width was found to be 35mm. All optimized values are listed in Table 1.

Table 1: Dimensions for the antenna geometry shown in Figure 1.

Parameter	Value
Length of the radiator patch (*L*)	53.0mm
Width of the radiator patch (*W*)	80.0mm
Length of the feed strip (*s*)	9.0mm
Width of the feed strip (*t*)	6.0mm
Separation of feed strip from the patch (*d*)	0.15mm
Air gap between substrates (*g*)	8.5mm
Slot length (l_s)	7.0mm
Slot width (w_s)	35.0mm
Slot position (from center of patch)	22.5mm

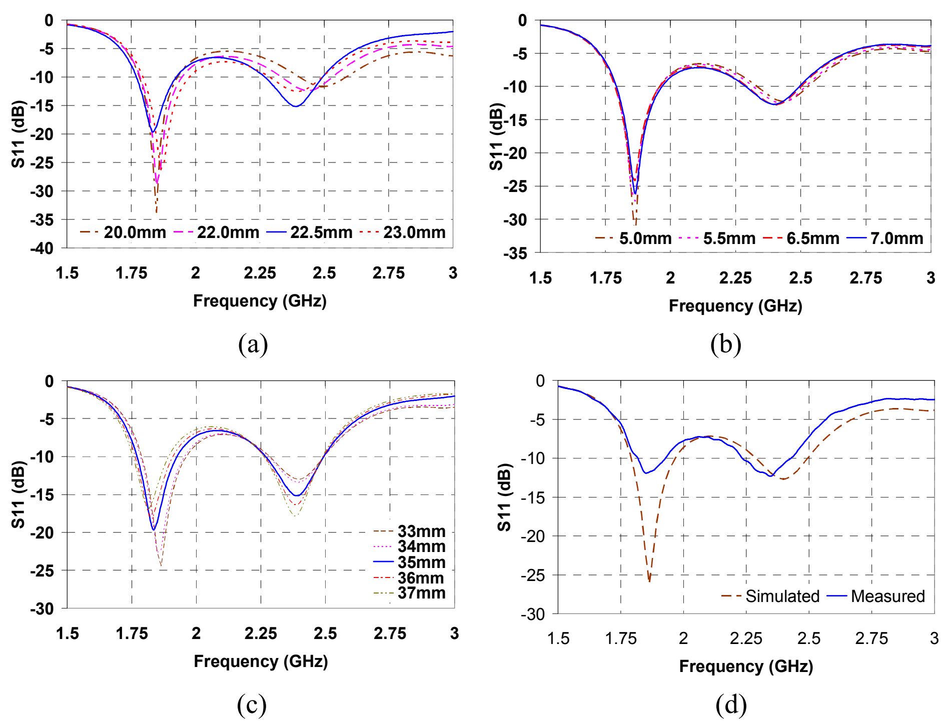
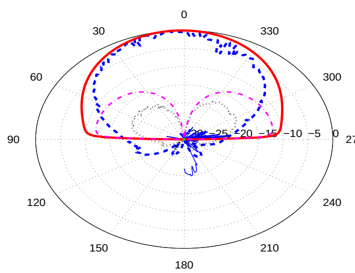


Figure 2: Return Loss Characteristics vs. Frequency Plots for (a) Different Values of Slot Position with l_s=6mm, w_s=32mm, (b) Different Slot Length Values with Slot Position= 22.5mm, w_s=32mm, (c) Different Values of Slot Width with Slot Position= 22.5mm, l_s=7mm (d) Comparisons of Measured and Simulated Results.

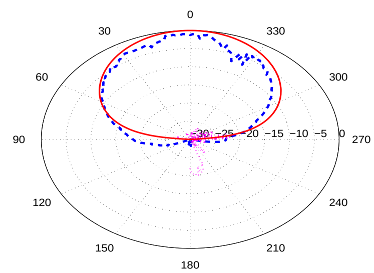
The prototype of the antenna with dimensions listed in Table 1 was fabricated and the return loss characteristics, and radiation patterns were measured. Return loss comparison plots are shown in Figure 2 (d). The radiation patterns were measured in an anechoic chamber and plotted in Figure 3 (a) and (b) at 1.8GHz frequency (Due to page restriction, patterns are shown at only one frequency in the band of operation). However at other frequencies also similar patterns were obtained. The measured and simulated gains are compared in Figure 3 (c). Gain of the antenna is very high (nearly 8dB) throughout the band of operation. All measured results fairly agree with the simulated values.

4. Conclusions

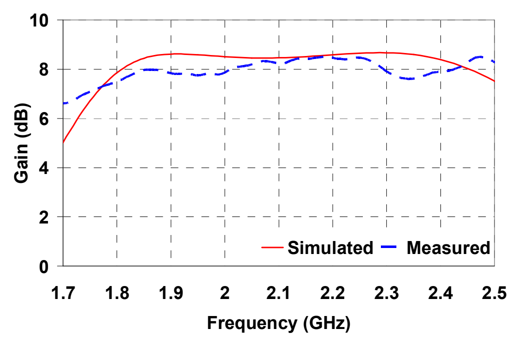
The coplanar capacitive microstrip antenna suitable for wireless applications has been presented. An impedance bandwidth of 35.9% (S_{11} <-6dB), good radiation patterns, and high gain of about 8dB in the band of operation have been obtained. The measured antenna characteristics are found to be in good agreement with the simulated results in the desired range of frequencies. The air gap can be reduced about 55% compared to similar antenna designs reported earlier by cutting a slot within the radiating patch. Besides reducing the air gap, it (slot) also enables the antenna to operate at lower frequencies due to reactive loading.



(a) E-plane Patterns at 1.8GHz



(b) H-plane Patterns at 1.8GHz



(c) Gain vs. Frequency Comparisons

Figure 3: Comparisons of Measured and Simulated Radiation Patterns, and Gain vs. Frequency Plots. In Radiation Patterns: Red (solid): Simulated Co-poln., Blue (dashed): Measured Co-poln., and Magneta (dash-dot) & Black (dotted): Cross-poln. (Note: H-cross (simulated) is invisible in Figure 3 (b) as it is well below -30dB).

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