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A capacitive fed microstrip patch antenna

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Abstract

In this paper, a microstrip reception apparatus on a suspended substrate with capacitive feed is presented capacitive feed is made by a space inside the rectangular fix around the feed point. The proposed antenna shows an a lot higher impedance transfer speed of about 47% (S11 < −10 dB). Impacts of key design boundaries, for example, the air hole between the substrate and the ground plane, the hole width between radiator fix and feed point, and the area of the feed point on the info qualities of the reception apparatus have been researched and talked about. A model of the reception apparatus is additionally manufactured and tested to confirm the plan. Estimated attributes of the receiving wire are in acceptable concurrence with the simulated results.

Keywords: Microstrip Patch Antenna Capacitive Fed Suspended Wideband

Introduction

Microstrip patch antennas are widely preferred for wireless communication systems that typically require antennas with small size, light weight, low profile, and low cost [1]. However, basic geometries of these antennas suffer from a small bandwidth, which is of the order of a few percent of the operational frequency. Therefore, it has been investigated by several researchers that the bandwidth of Microstrip Antenna (MSA) can be significantly improved. These alterations include, increasing the height (or thickness) of the substrate, cutting slots in the basic shapes, changing the shape of the geometry, using multi-layer techniques, metamaterials, or adding a shorting pin and so on [2-3] Typically, aperture and electromagnetic coupling methods of feeding are also used in stacked configurations to avoid the spurious radiations from the feed network while improving the impedance bandwidth [4, 5]. Many of these have relatively complex assembly, which in some cases is contrary to the fundamental attraction of MSAs. The coaxial probe is a simple feeding method for electrically thick substrates. In these substrates, the inductance of the probe may create the impedance mismatch which can be compensated by wideband impedance-matching networks, edge-coupled patches, stacked elements, shaped probes, and finally capacitive coupling and cutting slots on the patch [6, 7]. Several innovative feeding techniques have also been suggested to improve the bandwidth which included modification to a meandered [8] and L-probe [9] feeds. Alternatively, recently capacitive fed suspended MSA configurations with improvement of bandwidth are found in the literatures [10-15]. A rectangular MSA with a small coplanar capacitive feed strip is reported in [10]. In this antenna the radiator patch and a small feed patch are located on the same plane and the antenna substrate is located above the ground plane with an air gap separation. A circularly polarized (CP) MSA on a suspended substrate with a capacitive feed and as lot within the rectangular patch is proposed [12]. Moreover, an annular ring and narrow rectangular slots around the feed point in the radiating patch are presented in literature [16, 17], respectively. By choosing suitable dimensions of the ring or rectangular slot, the large probe reactance can be compensated. A good impedance matching over a wide bandwidth can be also obtained.

Antenna design and Configuration

The basic geometry of proposed antenna is shown in Figure 1. The antenna substrate is placed above the ground plane with a distance of H. As will be shown in Section III, this distance has an important role in maximizing the obtained bandwidth. The antenna structure is fabricated on an FR4 substrate with dielectric constant of 4.4, loss tangent of 0.02 and thickness of h=1.58mm. The patch dimensions are designed for central frequency (3.5GHz)

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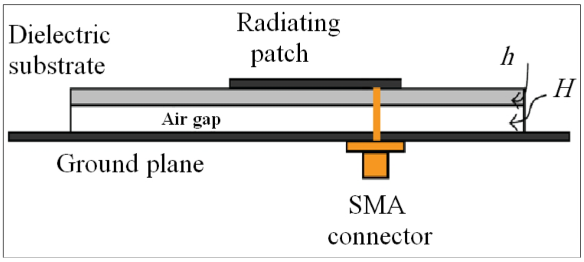
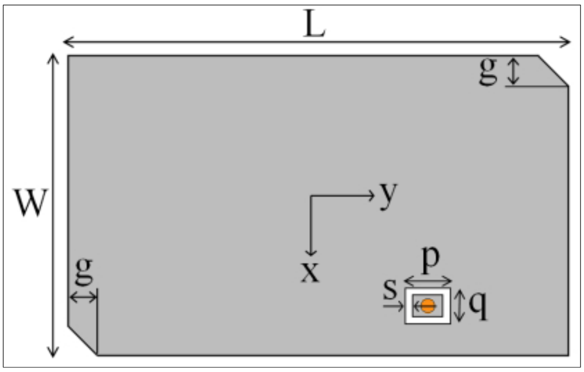
With regards to necessary corrections for the suspended dielectric [1]. A typical set of dimensions for the design are listed in Table 1.



(a) Cross-sectional view



(b) Top view

Fig 1: Geometry of the proposed patch antenna with capacitive fed

Table 1: Dimension of the Optimized Antenna Design

Parameter	mm	Parameter	mm
L	50	h	1.58
W	29.7	p	3.175
H	5	q	2.324
g	3	s	0.162
(W_f, L_f)	(10,11)	---	---

The configuration is based on the method of suspended capacitive fed MSA. The method described here is to etch a rectangular gap on the patch concentric with the probe feed. This introduces a series capacitance at the patch input and results in a much lower input resistance and therefore a usable input stripline impedance of 40 to 120 ohms, depending on the magnitude of the capacitance [12]. The idea behind the capacitive feed is quite simple. At resonance, the probe inductance and capacitance inherent to the antenna equivalent circuit cancel each other out, leaving real impedance [17]. The probe admittance is determined by enforcing a continuity of power flow at the aperture. The equivalent circuit elements for the probe that included in the patch impedance evaluation are:

$$L_P = -\frac{\mu_0 h}{2\pi}\left[\ln\left(\frac{kd}{4}\right)+\gamma\right]$$

$$d = diameter\ of\ probe \qquad (1)$$

with $\omega = 2\pi f$, $\mu 0 = 4\pi \times 10\text{-}7$ H/m and γ=0.5772 (Euler's constant). The capacitor is chosen such that its reactance is sufficient to cancel the residual reactance of the probe inductance. The required capacitance is:

$$C_m = \frac{1}{\omega_r^2 L_P} \qquad (2)$$

Where, w_r is the resonant frequency and L_P is the probe inductance. Thus, the extra capacitance brings the impedance back to resonance, and the wider bandwidth

Of the ticker substrate can be realized. Reference [17] gives approximate expression for the etched capacitors. The capacitors is:

$q' = q - 2s$, with s being the gap width; p and q are the

$$C_m = \sqrt{\pi}\left(\frac{q'}{p}\right)\varepsilon_0(\varepsilon_r+1)(q'+p) \qquad (3)$$

Capacitor length and width, respectively.

Parametric study on antenna performance

In the presented study, we used a very small rectangular gap around the feed point and retained the basic configuration of antenna with a substrate above the ground plane and an air gap between them. We further show that by properly choosing the size of rectangular gap and the height of the air gap, the impedance band width can be significantly improved. As previously mentioned, the radiating rectangular patch is designed using standard formulae for any desired resonant frequency. Key design parameters, which can be used to maximize the bandwidth of this antenna, are the air gap (*H*) at which the antenna substrate is located above the ground plane, the thickness of slot around the feed point (*s*), and the location of the feed point (*Wf,Lf*). In the following subsections, we examine the effects of these parameters on the antenna performance. All simulations are carried out using HFSS, which is based on the Finite Element Method (FEM).

Effect of air gap (H)

It is widely understood that as the effective substrate height increases or permittivity decreases, MSAs result in wider bandwidth. In the presented configuration, when two resonant frequencies are close enough these may merge to for single operational band with return loss below −10dB.

This may happen only for a certain range of values of "H". The effect of air gap on the return loss characteristics of the antenna is shown in Figure 2 and the bandwidth along with corresponding dimensions of key design parameters for each case are summarized in

Table 2. One of the reasons for the antenna impedance to be dependent on the air gap is the change in inductance of the probe pin [18]. If we increase the air gap and keeping the dimensions of other parameters as in Table 1, the resulting antenna will have two separate, narrow bands of operation. The shift in the resonant frequency is due to the fact that when air gap increases, the effective dielectric constant changes; and this leads to change in the effective dimensions of the patch. Although the impedance bandwidth obtained for H=6mm (48.10%) and H=6.5mm (49.43%) are slightly higher than that for H=5.5mm (46.93%), the latter is selected because it ensures a better minimum S11 from -10dB.

Effects of the gap width around the feed point (s)

The bandwidth of antenna can be restored to the maximum value by optimization the gap width (s). As shown in Figure 3 and Table 3, with the decrease in gap width, the return loss curve splits into two separate narrow bands, if all other parameters are kept constant. In addition, antenna input resistance increases and the input reactance decreases with a decrease in the width of gap. For s≤0.162mm, frequency band splits into two parts. For s≥0.162mm, even though we get approximately the same impedance bandwidth with as light reduction, increasing the dimensions of the gap width produces asymmetry in the radiation patterns and results in a reduction in useful bandwidth. The coupling capacitance due to the separation between the radiator patch and feed point (*s*) plays an important role in selecting the width of the gap. The value of gap capacitance due to *s* can be calculated using Equation (3) given in section II. Note that the inductive reactance offered by the probe [18] must betaken into account in the proposed configuration. However, from the observations we made in our detailed parametric study, we can use the minimum values of "*s*" as 0.162mm.

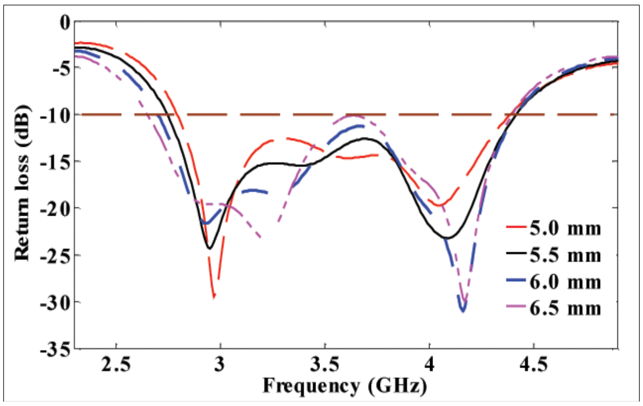


Fig 2: Return loss characteristics for different values of airgap (*H*). The other design parameters are kept constant in accordance with Table 1

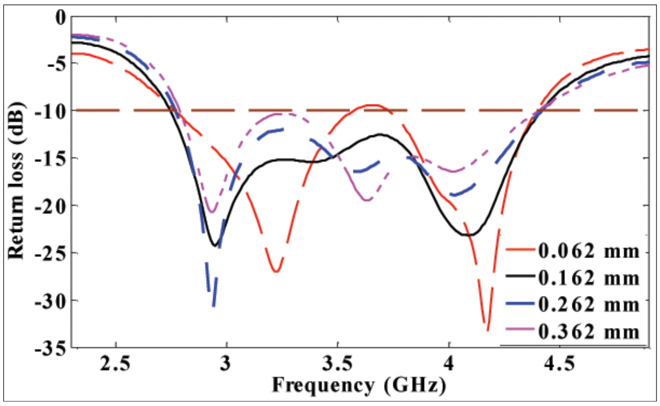


Fig 3: Effects of gap width (*s*) on impedance bandwidth

Table 2: Design Parameters for Various Curves Presented in Figure 2 Showing the Effects of the Air Gap on the Antenna Bandwidth

Air gap *H*, mm	Impedance bandwidth %, (GHz)
5	44.57% (2.79-4.39 GHz)
5.5	46.93% (2.74-4.42 GHz)
6	48.10% (2.70-4.41 GHz)
6.5	49.43% (2.65-4.39 GHz)

Table 3: Return loss characteristics for different values of air gap (*H*). The other design parameters are kept constant in accordance with Table 1

Gap width *s*, mm	Impedance bandwidth %, (GHz)
0.062	(2.77-3.57 / 3.73-4.39 GHz)
0.162	46.93% (2.74-4.42 GHz)
0.262	45.90% (2.77-4.42 GHz)
0.362	44.78% (2.79-4.40 GHz)

The effect of changing the length of the gap around the feed point (*p*, *q*) has also investigated. It is found that the bandwidth of antenna can be restored to the maximum value by decreasing length of the gap. The coupling capacitance due to the separation between the radiator patch and feed point play an important role in selecting the dimensions of the length of the gap. So, due to physical limitations and practical considerations of fabrication, the minimum values of "*p*" and "*q*" are used as 3.175mm and 2.324mm, respectively.

Effects of feed location (wf, lf)

The location of the feed point plays a critical role in obtaining the wide bandwidth for the proposed antenna. The feed location (Wf, Lf) are assigned different values. Its effects on the impedance bandwidth of antenna are shown in Figure 4 and Table 4. For Wf ≤ 8mm and Lf ≥ 12.5mm, the return loss characteristics curve splits into two separate or narrow bands of operation. When Lf=10mm and Wf=11mm, the impedance bandwidth is wider and reaches to 46.93% and the minimum S11 is −24.28dB.

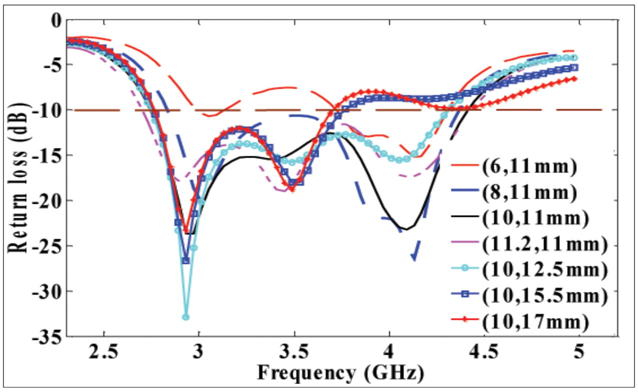


Fig 4: Effects of feed location (Wf, Lf) on impedance Bandwidth

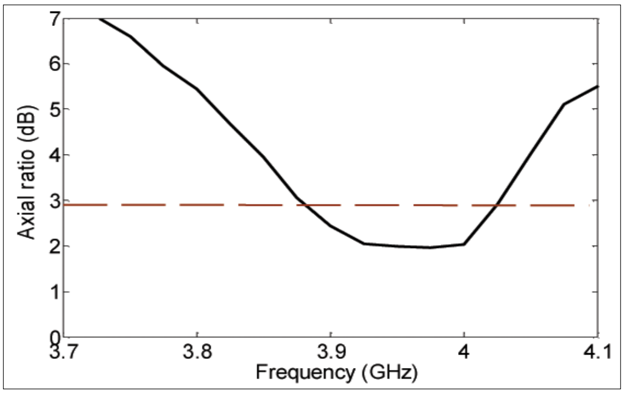


Fig 5: Simulated axial ratio in the broadside direction for the antenna studied in Figure 1

Table 4: Impedance bandwidth for the antenna for varying feed location (wf, lf)

Feed location (W_f, L_f), mm	Impedance bandwidth %, (GHz)	Minimum S_{11}, dB
(6,11)	14.70% (3.72-4.31 GHz)	-15.31
(8,11)	42.78% (2.83-4.37 GHz)	-26.47
(10,11)	46.93% (2.74-4.42 GHz)	-24.28
(11.2,11)	48.74% (2.70-4.44 GHz)	-19.07
(10,12.5)	44.41% (2.75-4.32 GHz)	-32.91
(10,15.5)	30.93% (2.76-3.77 GHz)	-26.74
(10,17)	29.37% (2.76-3.71 GHz)	-23.41

Simulation Studies for Circular Polarization Operation In the proposed antenna by a corner truncated microstrip patch, a single-feed, CP MSA can easily be obtained. The dimension of truncated corners is shown in Table 1. Figure 5 presents the simulated axial ratio of designed antenna at 0° in elevation angle. The simulated 3-dB AR bandwidth at 4GHz is 4.1% (3.87–4.03GHz). This axial ratio bandwidth covers the impedance bandwidth of the antenna.

Conclusion

A microstrip patch antenna with a capacitive feed is proposed here. After presenting the basic configuration involving a rectangular patch and a rectangular gap around the feed point, the effects of all key design parameters are studied for optimum design. Return loss bandwidth (below − 10dB) of nearly 47% has been obtained for a wide range of frequencies. When the gap width dimension around the feed point is increased, the antenna bandwidth appears to be lessened. On the other hand, the gap width dimensions cannot be reduced below limits to avoid problems in soldering the probe pin. The antenna can be designed at any frequency to get the similar performance by selecting proper air gap value and corresponding dimensions of the patch. Based on the results presented here, the proposed feed scheme is versatile and can be employed for designing simple to fabricate wideband microstrip patch antennas.

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