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A WIDEBAND RECTANGULAR MICROSTRIP ANTENNA WITH CAPACITIVE FEEDING

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ABSTRACT

A rectangular microstrip patch antenna with capacitive feeding is presented here. To overcome various problems in other feeding, capacitive feeding technique has used. The designed antenna consists of stacked arrangement of a rectangular radiating patch and a small feeding strip which is fed by coaxial feeding probe. Using capacitively fed rectangular patch antenna, the bandwidth achieved is 40%, for operating frequency of 2.427GHz. The effect of key design parameters like feeding strip length, feeding strip location, and feeding probe height are studied.

Keywords: microstrip patch antenna, capacitive feed, wideband antennas, proximity coupling.

INTRODUCTION

Microstrip antennas are most popular because of its numerous advantages in wireless communication systems that typically require antennas with light weight, low volume, easy to fabricate, low cost, and planar configuration which can be easily made conformal to hot surface [1]. Basic geometries of these antennas suffer from a narrow bandwidth, which is of the order of a few percent of the operational frequency. The bandwidth can be increased by various techniques like the use of thick substrate and low dielectric constant, multiple-resonator technique in either coplanar [2, 3] or stacked configurations [4]. Various feeding schemes are given in many standard books [1]. Many of these feeding techniques can improve the bandwidth, but provide asymmetry in radiation pattern. With considering all these effects, the use of a capacitive feeding strip with coaxial feeding probe is proved to increase the bandwidth [5, 6]. A rectangular microstrip antenna with a proposed rectangular strip provides the improved bandwidth with nearly symmetric radiation pattern.

Design of the rectangular patch

To design a rectangular patch microstrip antenna, the following parameters such as dielectric constant of the substrate (ε_r), the resonance frequency (f_r), and the height of the substrate (h) should be considered for calculating the length and the width of the patch

a) Length (L) and width (W) calculation

For TM_{01} mode, the length of the patch can be calculated by the following equation [7]:

$$L = \frac{c}{2f\sqrt{\varepsilon_r}} \tag{1}$$

where c is the speed of light, f is the operating frequency, and ε_r is the dielectric constant. The width of the patch can be $L<W<2L$, for good performance $W=1.5L$ is chosen.

b) Calculating the effective dielectric constant (ε_{eff}). The following equation gives the effective dielectric constant [8, 9]:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+10h/W}}\right) \tag{2}$$

where h is the height of the dielectric substrate

c) Calculating the length extension (Δl). The following equation gives the length extension in terms of (W/h) ratio and the effective dielectric constant ε_{eff}

$$\Delta l = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.813\right)} \tag{3}$$

d) Calculating the effective length of patch (L_e). The effective length of the patch is given by the following equation:

$$L_e = \frac{c}{2f\sqrt{\varepsilon_e}} \tag{4}$$

e) Calculating the actual length of patch (L)

The following equation gives the actual length of the patch as:

$$L = L_e - 2\Delta l \tag{5}$$

Basic antenna configuration details

Figure-1 (a, and b) shows the geometry of the proposed antenna in which the large upper rectangular patch with dimension (WxL) act as a radiator and the small lower one with dimension (lxs) serves as a feeding strip which couples the energy to the radiator patch by capacitive means. Coaxial probe is used for the excitation of the feeding strip as shown in Figure (1-b). The radiating patch is printed on an FR-4 dielectric substrate with

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ε_{rr}=4.4, loss tangent=0.02, and thickness h_r=0.32cm (0.054 λ_d), where λ_d is the wavelength inside substrate. The feeding strip is printed on RT Duroid 5880 dielectric substrate with ε_{rf}=2.2, loss tangent =0.0009, and thickness h_f=0.833cm (0.1λd). The operational frequency for the designed antenna is 2.427GHz. Specification of the antenna for 2.427GHz are radiating patch length (*L*) 2.88cm, width (*W*) 4.4 cm, which is based on the formulas (1-5), the feeding strip length (*l*) 0.9cm, width (*s*) 0.22cm and located at (x_f=0,y_f=1.98). Table-1 shows the geometrical parameters of the design.

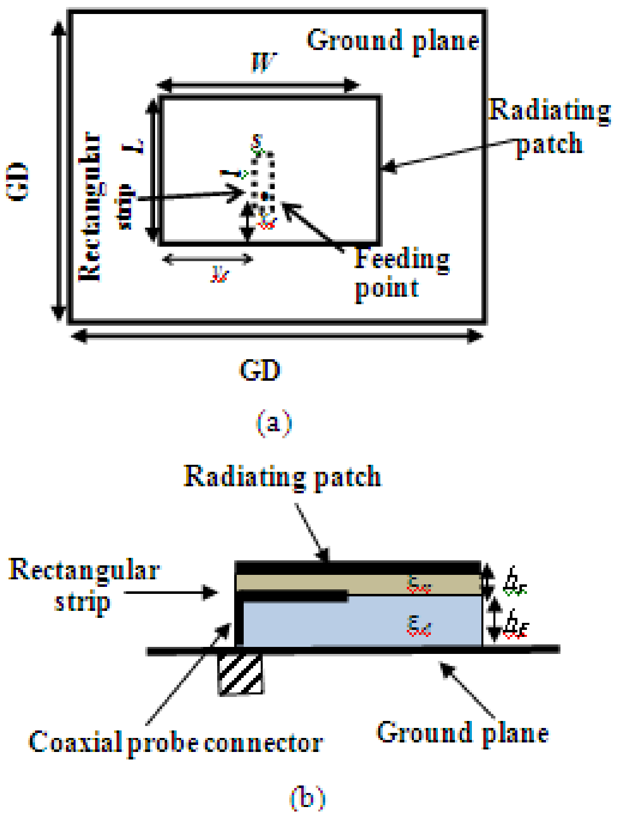

Figure-1. Geometry of the proposed rectangular patch microstrip antenna capacitively fed with a small stacked rectangular strip. (a) Top view, (b) Side view.

Table-1. Antenna design parameters.

Parameter	Dimension	unit
Operating frequency (f_r)	2.427	GHz
Primary radiating patch length (L)	2.8	cm
Radiating patch width (W)	4.42	cm
Dielectric constant of radiating patch (ε_{rr})	4.4	--
dielectric substrate thickness of radiating patch (h_r)	0.32	cm
Effective dielectric constant of radiating patch (ε_{rreff})	3.995	--
effective length of radiating patch (L_e)	3.09	cm
actual length of radiating patch (L)	2.88	cm
Dielectric constant of feeding strip(ε_{rf})	2.2	--
dielectric substrate thickness of feeding strip (h_f)	0.833	cm
Length x width of feeding strip (lxs)	0.9x0.22	cm^2
Feeding point of feeding strip (x_f,y_f)	(0,1.98)	cm,cm

RESULT AND DISCUSSIONS

The effects of various key parameters on antenna design are studied using MW- Office version 7 ,2009 which is a method of moments (MoM) based electromagnetic (EM) software. Characteristic of an antenna can be optimized by properly choosing the size of feeding strip, the separation between the radiating patch and the feeding strip, (h_r), and the feeding strip height from the ground plane (h_f). Note that the patch dimensions, its dielectric height, and the feeding strip width are not changed through the work.

Effect of feeding probe height (h_f)

The effect of variation of (h_f) on the voltage standing wave ratio (VSWR) bandwidth of the antenna is listed below in Table-2. The height of the coaxial probe substrate (h_f) increase while keeping the other parameters constant (l=0.9cm, x_f=0, y_f=1.98cm). Increasing the height of the feeding substrate results in increasing the inductance of the feeding pin and decreases its capacitance.

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Table-2. Effect of variation of h_f on VSWR bandwidth of antenna.

h_f in cm	0.42	0.833	1.25
h_f in λ_d(cm)	0.05	0.1	0.15
Bandwidth(GHz)	2.23-2.38	1.94-2.91	1.7-2.5
VSWR at 2.427GHz	------	1.38	1.77
Bandwidth %	6.5	40	38

We have observed the maximum bandwidth of 40 % has obtained at thickness of 0.833cm (0.1 λ_d)

Effect of feeding strip length (*l*)

The dimension and location of the feeding strip play an important role in increasing the bandwidth of the proposed antenna. Effect of variation of feeding strip length (*l*) on VSWR bandwidth of antenna keeping h_f=0.833cm, x_f=0, y_f=1.98cm constant is listed in Table-3.

Table-3. Effect of variation of feeding strip length on VSWR bandwidth of antenna.

Feeding strip length *l*(cm)	1.08	0.9	0.72
Bandwidth(GHz)	1.95-2.7	1.94-2.91	2.-2.3,2.44-3.78
VSWR at (2.427GHz)	1.1	1.38	-------
bandwidth%	32.25	40	13.9, 43.1

It has been observed from the result, VSWR is increased by increasing the feeding strip length. The input reactance decreases with an increase in the feeding strip length. For *l*=0.72cm, the VSWR exceed 2 at operating frequency 2.427GHz even though we get a larger impedance bandwidth. The optimum value is that when *l*=0.9cm

Effect of feeding strip position

The feeding strip is located under the radiating patch at the center of its non-radiating edge. The variation of the feeding strip location from the edge toward the patch center keeping *l*=0.9cm, h_f=0.833cm, and y_f=1.98cm constant is shown in Table-4.

Table-4. Effect of variation of feeding strip position on VSWR bandwidth of antenna.

Feeding strip location from edge of the non-radiating patch edge center (x_f cm)	0	0.18	0.36
Bandwidth(GHz)	1.94-2.91	1.98-2.84	2-2.7
VSWR at (2.427GHz)	1.38	1.34	1.45
bandwidth%	40	35.6	29.8

It has been observed from the result, VSWR is maximum when the strip located under the edge of the non-radiating edge center of the patch.

From all the studied case, the optimum parameters for wideband impedance bandwidth are *l*=0.9cm, h_f=0.833cm and x_f=0. Figure-2 shows the VSWR for the designed antenna. The VSWR obtained is 1.38. This is considered a good value, as the level of mismatch is not very high. A high VSWR means the port is not properly matched. The impedance bandwidth of 40% for VSWR≤2 covering frequency band from (1.94 to 2.91) GHz is obtained as shown in Figure-2. The smith chart in Figure-3 shows the impedance matching at the design frequency of 2.427GHz. To match the antenna, the impedance locus need to be shifted as near as possible to the center of the smith chart (matching point) to obtain a very low return loss at resonant frequency. As can be observed the impedance matching point is close to the center of the smith chart. Figure-4 shows the simulated result for return loss (RL) of the antenna against the frequency. As can be observed from the Figure, S11 (RL) plot has a magnitude of much less than -10dB at the operating frequency. The return loss for the antenna is -16

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dB at 2.427GHz. A negative value of return loss shows that this antenna had not many losses while transmitting the signals. The gain 7.03dB is obtained at 2.427GHz as shown in Figure-5, which is considered a high value. Since a microstrip patch antenna radiates normal to its patch surface, the far field components E_φ (φ=0^o) and E_θ (φ=90^o) for the two principal planes, E - and H –planes respectively, would be important. Figure-6 shows the normalized value of the radiation pattern occurs at 2.427GHz. It can be noticed that the pattern in both planes have uniform shape (symmetric with respect to the zenith). The current distribution at 2.427GHz is shown in Figure-7.

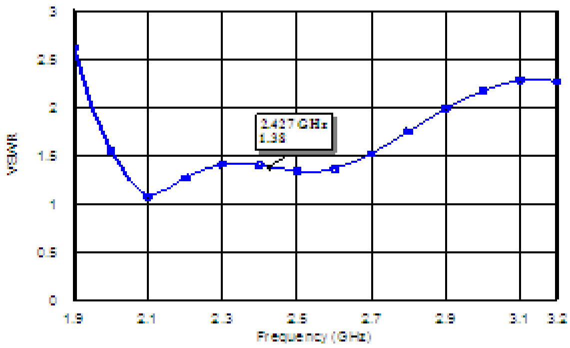

Figure-2. VSWR with frequency.

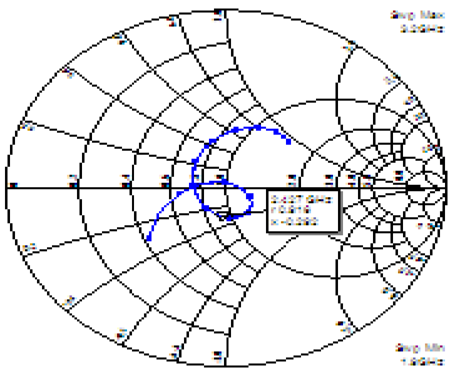

Figure-3. Smith chart.

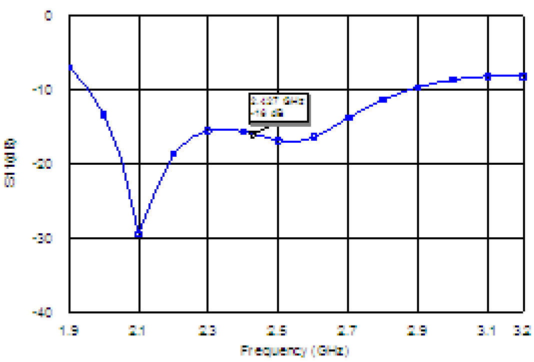

Figure-4. Return loss with frequency.

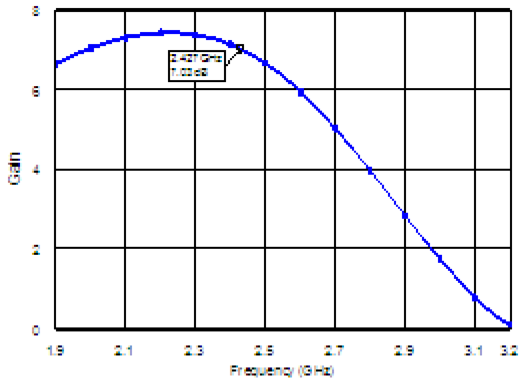

Figure-5. Gain with frequency.

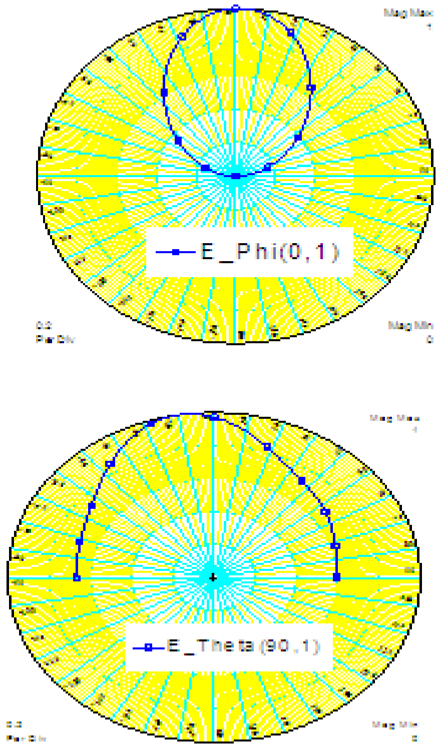

Figure-6. 2D Radiation pattern of antenna.

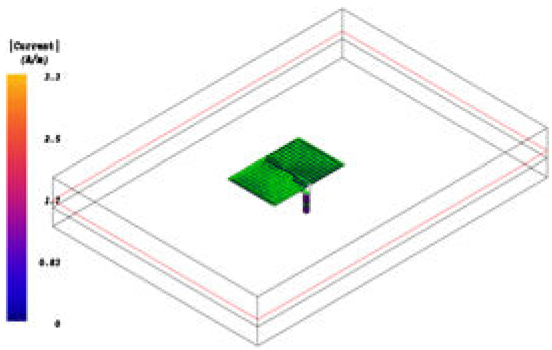

Figure-7. Current distribution of antenna.

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CONCLUSIONS

The stacked capacitive coupled probe fed microstrip antenna suitable for wireless application has been presented. The proposed antenna, uses capacitive feeding instead of direct feed, offers wide impedance bandwidth of 40%, good radiation pattern, and high gain of about 7 dB at operating frequency 2.427GHz have been obtained. Different design parameters with their effects are studied. The feeding strip on thick substrate (0.1 λ_d) is helpful in increasing the bandwidth.

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