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Analysis and Design of Capacitive Coupled Wideband Microstrip Antenna in C and X band

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Abstract— In this paper design and analysis of capacitively fed wideband microstrip antenna suspended above the ground plane is presented. It is demonstrated that the proposed antenna can be used for wideband application with impedance bandwidth of about 51.13% at center frequency 7.255 GHz with a good gain in various microwave bands (C and X band). This antenna has utilized the concept of capacitive coupling for bandwidth enhancement. Suspension of structure above ground plane has also been utilized for the enhancement of bandwidth. In this proposed antenna probe feeding is provided to the feed strip and the parasitic patch is excited by the capacitive coupling. The antenna configuration can be used where unidirectional radiation patterns are required over a wide bandwidth. All the simulation work is done using IE3D software.

Index Terms—Microstrip antennas, Capacitive fed, Wideband, Absolute gain, Efficiency.

I. INTRODUCTION

Microstrip antennas are suitable for modern broadband applications because of their desirable characteristics [1]-[3]. Although microstrip antennas in their basic form exhibit limited bandwidth, it has been shown by several researchers that the bandwidth can be significantly improved by altering the basic geometry and/or feed or by using impedance matching technique [2]. However most of these geometries employ stacked multiple metal/dielectric layers [4], or use modified probe shape 5]-[7], which elude the primary advantages of microstrip antennas such as ease of fabrication and assembling [8].

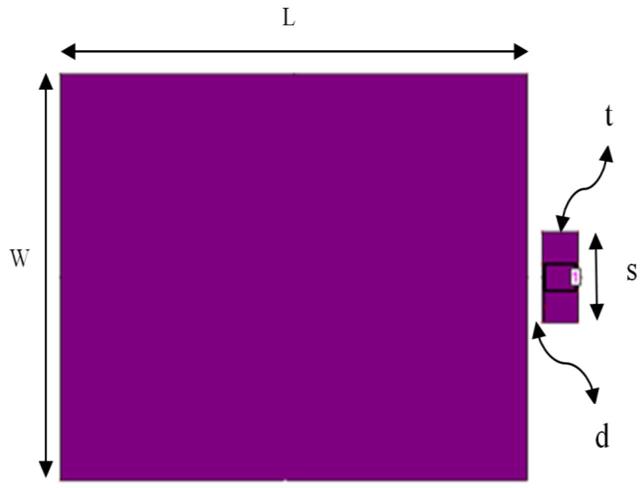
The proposed structure uses a coplanar structure so as to make fabrication and assembling easy. The structure again uses capacitive coupling for exciting parasitic patch. This capacitive coupling result in the enhancement of the bandwidth. Again the dielectric substrate is suspended above the ground plane which results in the reduction of the effective dielectric constant of the substrate. Since the reduction in dielectric constant results in the enhancement of bandwidth. So here we are getting a wide bandwidth operation.

The proposed antenna structure is showing a 51.13% bandwidth at the center frequency 7.255 GHz. The antenna bandwidth extends from the lower cut off frequency of 5.4 GHz to upper cutoff frequency of 9.11 GHz. Thus the proposed antenna is working in microwave bands i.e. C band (4-8 GHz) and X band (8-12 GHz) with the resonating frequencies 5.7 GHz and 8.1 GHz with a return loss of -35.5 dB and -22.5 dB respectively.

Further we are getting the absolute gain 4.63 dBi at frequency 5.7 GHz and 4.69 dBi at frequency 8.1 GHz.

II. ANTENNA GEOMETRY AND ITS OPTIMIZATION

The basic geometry of the antenna is shown in Fig. 1 and optimized dimensions are listed in Table I. The configuration is basically a suspended microstrip antenna in which radiating patch and the feed strip are placed above the substrate of thickness “h” mm. A long pin SMA connector is used to connect the feed strip which capacitively couples the energy to a radiating patch. In this section, we briefly discuss the effect of key design parameters on the antenna performance. These include air gap (g), separation between feed strip and the radiator patch(d), and the length(t) and width(s)(feed strip dimensions). The dielectric constant of the substrate used is 2.32 and the thickness is 1 mm. The substrate is suspended above the ground plane with an air gap(g) of 6 mm. All parameters are optimized using IE3D which is a method of moments (MoM) based electromagnetic (EM) software.



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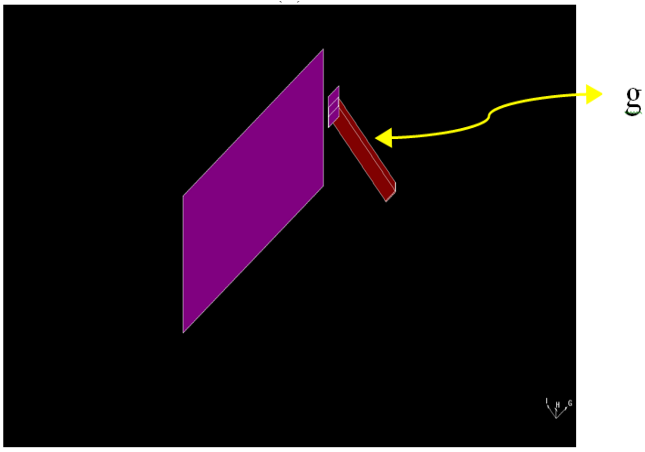

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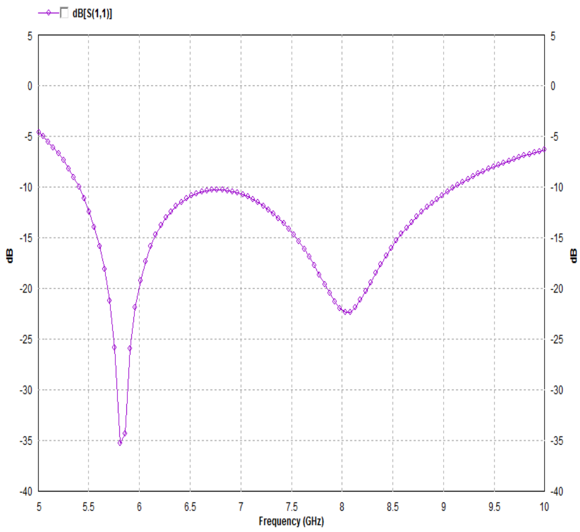
Fig 1 (a) Top view of antenna (b) 3D view of antenna

Table 1: Optimized parameter of Antenna

Parameter	Value
Length of the radiator patch (L)	14 mm
Width of the radiator patch (W)	8.5 mm
Length of the feed strip (s)	2.8 mm
Width of the feed strip (t)	2.0 mm
Separation of feed strip from the patch (d)	0.8 mm
Air gap between substrates (g)	6.0 mm
Relative dielectric constant (ε_r)	2.32
Thickness of substrate (h)	1.0 mm

III. RESULTS AND DISCUSSIONS

The optimized structure is simulated using IE3D software. In course of the simulation, the return loss plot and VSWR plot is observed with respect to frequency which is given in fig. 2. From the return loss plot we are observing an impedance bandwidth of 3.71 GHz with lower and upper cut off frequency extending from 5.4 GHz to 9.11 GHz with center frequency of 7.255 GHz. We observe the same results from the VSWR plot.



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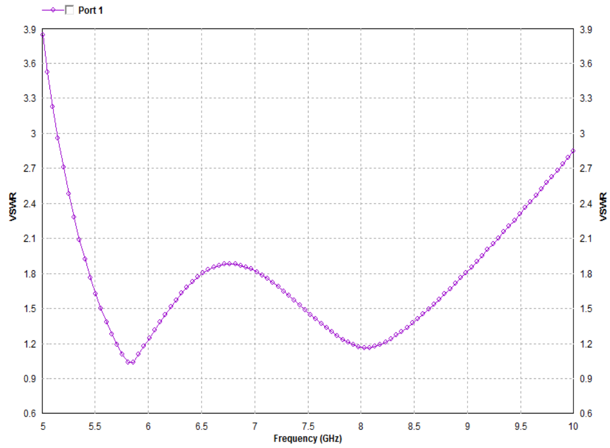

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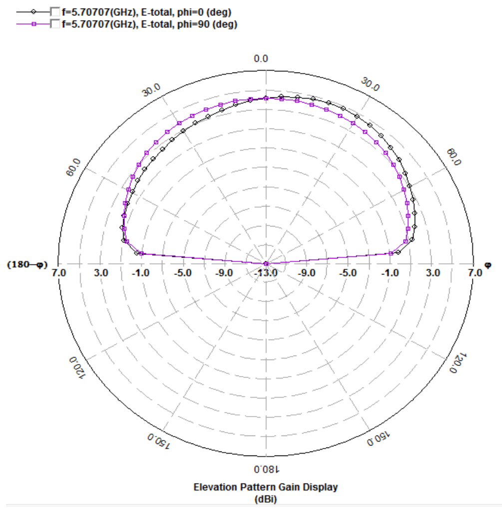
Fig. 2 (a) Return loss plot (b) VSWR plot

The return loss plot is showing two resonant frequencies at 5.7 GHz and 8.1 GHz with return loss of -35.5 dB and -22.5 dB respectively. VSWR plot is showing maximum impedance matching at these resonant frequencies.

A. Radiation Pattern

The proposed antenna is showing an effective return loss from 5.4 GHz to 9.1 GHz. That is why, the antenna should have similar radiation pattern in this entire range. For this the radiation pattern at three frequencies (5.7 GHz, 7.22 GHz and 8.13 GHz), lying within the range, is observed. The two dimensional E-plane radiation patterns at these frequencies are shown in the fig 3. The three dimensional radiation patterns for these frequencies is shown in fig 4.



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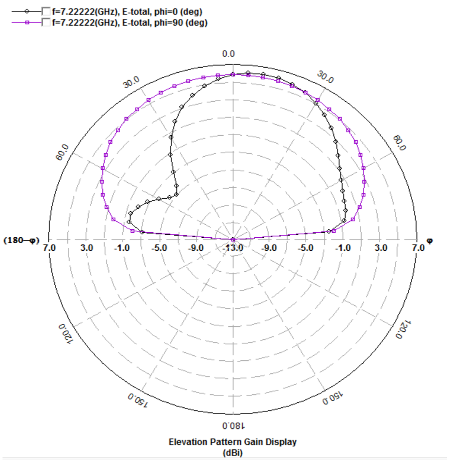

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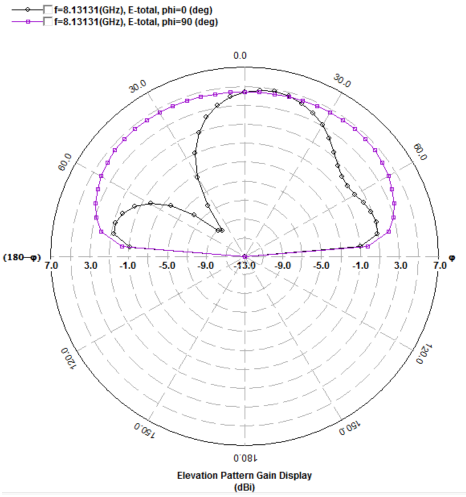

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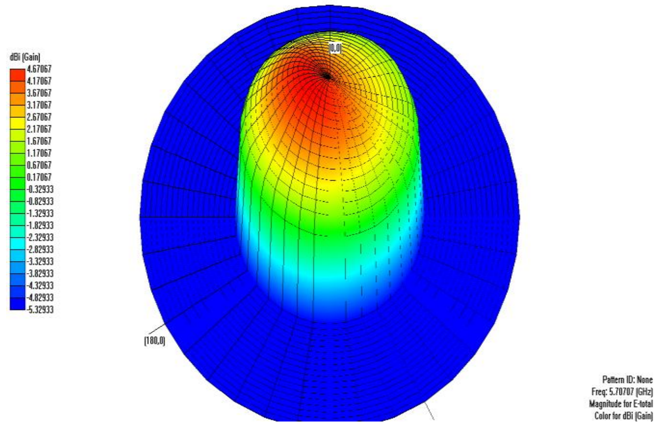
Fig. 3 (a) Radiation pattern at 5.707 GHz (b) Radiation pattern at 7.222 GHz (C) Radiation pattern at 8.13 GHz

From the 2D radiation pattern plot, we observe an absolute gain of 4.63 dBi, 5.82 dBi and 4.6 dBi at frequency 5.707 GHz , 7.22 GHz and 8.13 GHz respectively. Thus we are getting a similar variation of gain with in the entire band. Further the 3 dB beamwidth of the antenna is 142.6^0, 110^0 and 160^0 respectively at these frequencies. Thus beamwidth is also showing a similar variation within the entire range. We are also observing a variation in radiation pattern for phi = 0^0 at higher frequency. But it remains constant for phi = 90^0 for all the frequencies. The 3 dimensional radiation pattern is also shown in fig 4. This pattern is also showing a similar radiation performance for the specified frequency. Thus we can conclude that the proposed antenna has similar radiation performance for entire band extending from 5.4 GHz to 9.1 GHz with center frequency 7.25 GHz and bandwidth 3.7 GHz.



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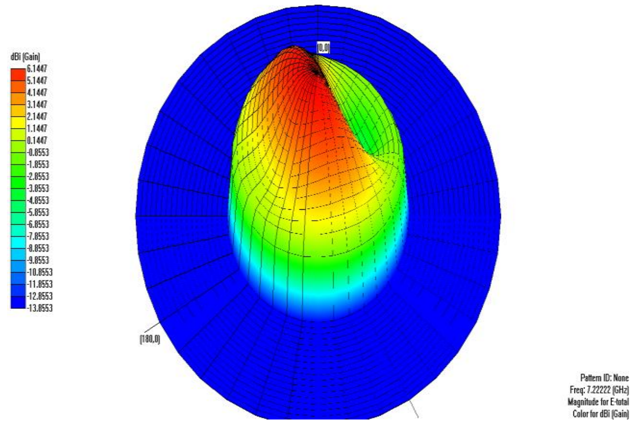

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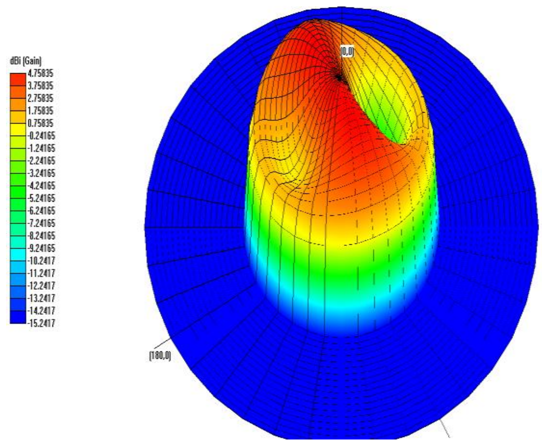

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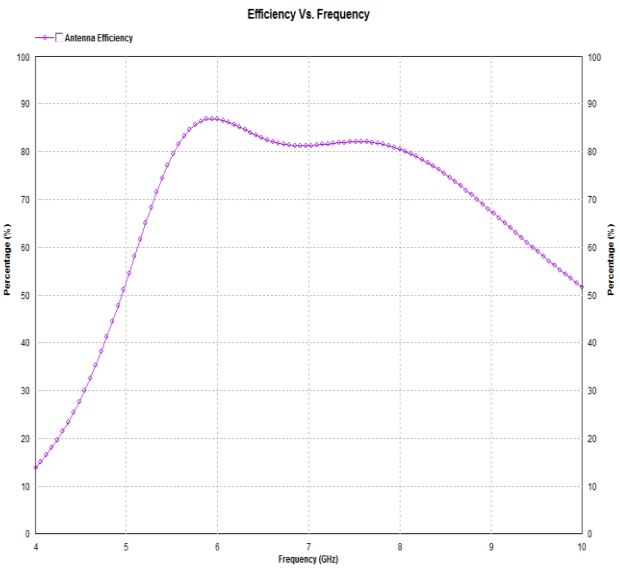
Fig. 4 (a) 3D Radiation Pattern at 5.707 GHz (b) 3D Radiation Pattern at 7.22 GHz (c)Radiation Pattern at 8.13 GHz

B. Gain and Efficiency

The gain and efficiency variation of the proposed antenna with respect to frequency is observed by IE3D simulation. For efficiency we are taking both antenna efficiency and radiation efficiency under consideration. The efficiency plot is shown in fig 5. The absolute gain plot is shown in fig 6.



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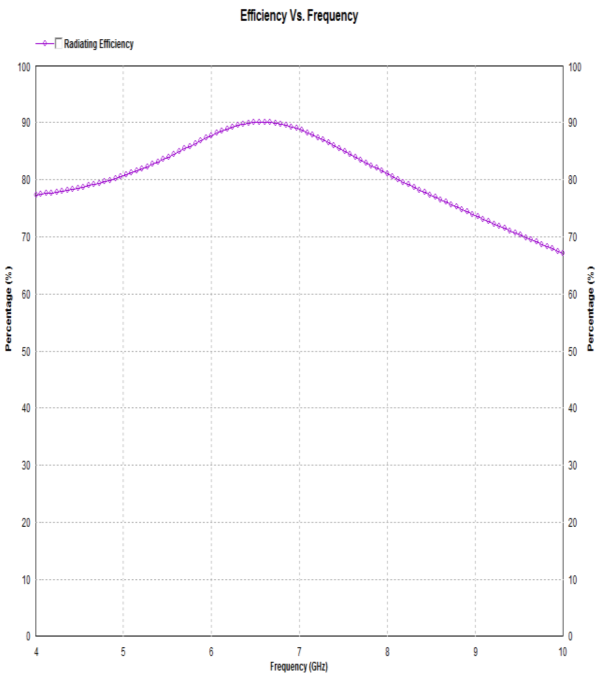

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Fig 5 (a) Antenna Efficiency plot
(b) Radiation Efficiency plot

From the antenna efficiency plot, we are getting an efficiency of 84%, 81.59% and 79.5% at frequency 5.707GHz, 7.22 GHz and 8.13 GHz respectively. Thus we are getting average antenna efficiency more than 80% for the entire range (5.4 GHz – 9.1 GHz) of operation. Further the radiation efficiency at these frequencies is 85.5%, 87.5% and 80% respectively. Thus we are getting average radiation efficiency more than 85% for the entire range of operation.

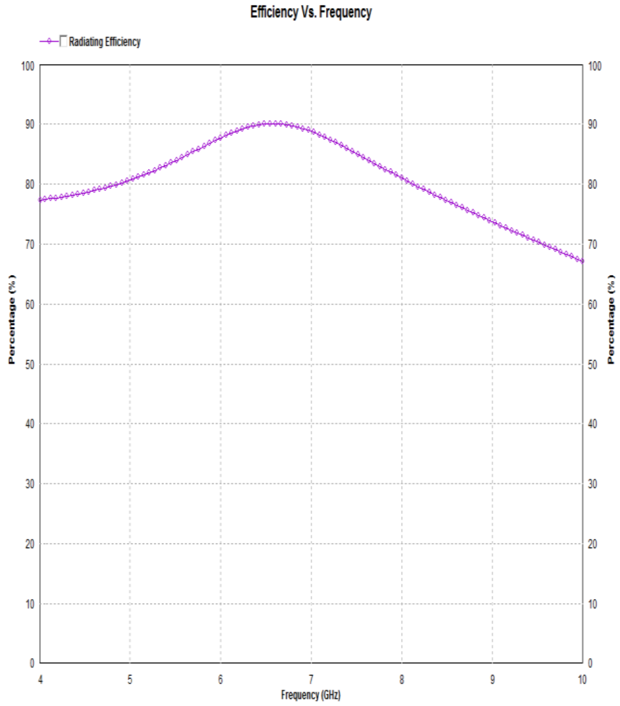

Fig 6 Gain plot

The variation of the absolute gain of the proposed antenna is plotted in fig 6. From the plot the absolute gain is 4.63 dBi, 5.82 dBi and 4.6 dBi at frequency 5.707 GHz, 7.22 GHz and 8.13 GHz respectively. The maximum gain of this wideband antenna is 6 dBi at 6.8 GHz. The average absolute gain of the antenna is above 4.5 dBi for entire frequency range from 5.4 GHz to 9.1 GHz.

All the simulated results are summarized in the table below. From the table it is clear that for the designed capacitive fed wideband antenna has nearly similar radiation performance in the entire frequency range from 5.4 GHz to 9.1 GHz. We are also getting sufficient gain in this range with good return loss and VSWR.

Table 2: Simulated Results of Antenna

Frequency (GHz)	Absolute Gain(dBi)	Antenna Efficiency(%)	Radiation Efficiency(%)
5.707	4.63	84	85.5
7.22	5.82	81.59	87.5
8.13	4.6	83	79.5

IV. CONCLUSION

A capacitive fed wideband microstrip antenna suspended above ground plane is designed. The operating bandwidth of the designed antenna is 51.13% with center frequency 7.25 GHz. The antenna operates in the frequency range from 5.4 GHz to 9.1 GHz. The antenna is showing a very good radiation performance for the entire operating band. The average absolute gain of the designed antenna is above 4.5 dBi in the operating band. The antenna has maintained an antenna efficiency of more than 80% and a radiation efficiency of more than 85% in its entire operating range. Thus this designed can be utilized in the microwave C band (4-8 GHz) and X band(8-12 GHz) for wideband communication.

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