# Designing of Wideband Microstrip Patch Antennas at 2.4 GHz

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## ABSTRACT
This paper presents designing of capacitive fed and electromagnetic coupled MSA. These are designed to overcome the disadvantage of MSA i.e. narrow bandwidth. The antenna design is simulated using HFSS software. Antenna is designed at frequency of 2.4 GHz. Capacitive fed antenna provides wide bandwidth. It's working frequency range 2.275-2.905GHz with return loss of less than -10 db. Capacitive fed with electromagnetic coupling MSA antenna works on frequency range 1.915-2.83GHz. Hence bandwidth enhancement can be obtained by ECMSA. The proposed antenna designs can be used in WLAN band 2.4 GHz, USB dongle, UTMS & Bluetooth communication.

## Keywords
Microstrip Patch Antenna (MSA), Capacitive fed MSA, Electromagnetic coupled MSA (ECMSA)

## 1. INTRODUCTION
Antenna is a transducer designed to transmit as well as receive electromagnetic waves. Also the antenna is transitional structure between free space and a guiding device. The guiding device or transmission line may be coaxial line or hollow pipe. Microstrip patch antenna consists of metallic patch on ground substrate. The patch can take many different shapes. This antenna can be mounted on the surface of high performance. It is a popular printed resonant antenna for narrow-band microwave wireless links that require semi-hemispherical coverage. The effective techniques used for the enhancement of the bandwidth are the utilization of stacked, shorted patches, and extra microstrip resonators. The technique of stacked patches is based on the fact that the bandwidth is in general proportional to the antenna volume measured in wavelengths but at the same time a relatively large volume is a disadvantage for many applications. Superior to these methods is the techniques of slot loading or texturing the patches by slits because they ensure the small size and the low profile of the antenna. The utilization of additional parasitic patches of different size directly- or gap-coupled to the main patch is an effective method but results to an increased antenna size which would also be undesired

a) The texturing of narrow or wide slits at the boundary of the microstrip patch (Suspended technique) & using capacitive fed.

Suspended microstrip antennas provide wide bandwidth due to the reduced effective dielectric constant and surface waves. The air gap is introduced in between substrate and ground. A wide band circularly polarized truncated square Microstrip antenna with capacitive feeding is suspended over the ground plane offers better impedance BW in the frequency range 1.15 -1.6GHz [1]. In [2] inverted U- probe fed increases the electrical length of the patch. It provides 24.5% of 2:1 VSWR bandwidth. Suspended E shaped microstrip antenna with a capacitive coupling feed is designed in order to be employed for Wireless communication applications. Employing only a single patch, a high impedance bandwidth is achieved about 23.1% [7].Coplanar capacitive coupled suspended microstrip compact antenna for wireless applications exhibit the fractional impedance bandwidth of nearly 25% [10]. Capacitive fed antenna is most very effective antenna. The antenna structure with capacitive fed can achieve impedance bandwidth up to 51.13% in C and X band [11].

b) The loading of the surface of the printed element with slots of appropriate shape

Antenna array used for worldwide interoperability for microwave access (WiMAX) and wireless local area network (WLAN) applications [4].Dual E-shaped antenna is designed by cutting four notches in the rectangular shaped microstrip antenna also shows good enhancement in bandwidth and gain [5].In [6] two square slots rectangular antenna structure gives bandwidth of 311 MHZ. In novel E-shaped microstrip antenna the edges of the antenna have been widened to achieve wide bandwidth. Which is frequency band of 5.15-5.35GHz .This frequency range may be used for Wi-Fi application [8]. In [9], employing two different L slots, a good bandwidth and a perfect impedance match can be obtained. The ECMSA is used to achieve wide impedance bandwidth, while the gaps and stubs-loaded patch is used to obtain broad-beam. This electromagnetic coupling microstrip patch antenna (ECMSA) antenna is based on a two-layer [12].

This paper describes two designs of wideband MSA. Capacitive fed MSA provides bandwidth of 630 MHz (26.25%). The obtained bandwidth with electromagnetic coupling is 915 MHz (38.12%).

## 2. CAPACITIVE FED SUSPENDED E SHAPE MSA

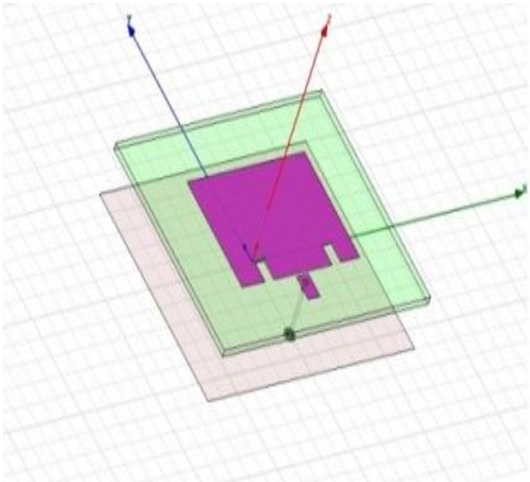

**Fig 1: Capacitive fed MSA**

The above antenna is fabricated on 1.6 mm thick FR4 substrate. The length and width of dielectric substrates are 60 mm & 55 mm. The conducting ground plane is rectangular in shape with dimensions 55 mm length & 60 mm width. The patch is E shaped with dimensions W & L mentioned in Table 1.

A capacitive fed wideband microstrip patch antenna is designed shown in Figure 1. The configuration is basically a suspended with air gap of 11mm. Microstrip antenna in which radiating patch and the feed strip are placed above the substrate. The capacitive patch is rectangular with dimensions mentioned in Table 1. A long pin SMA connector is used to connect the feed strip which capacitive couples the energy to a radiating patch. The resonant frequency of the antenna must be selected appropriately. The resonant frequency selected for design is 2.4 GHz. The dielectric material selected for design is glass epoxy which has a dielectric constant of 4.4.

Antenna dimensions can be calculated by following using formulas:

## 2.1 Width of Patch (W)

The width of the MSA is given as

$$W = \frac{c}{2\,f\,o\,\sqrt{\frac{\varepsilon\,r\,+1}{2}}}$$

c=3*10^11 mm/s, $f\,o$=2.4GHz, ε $r$=4.4

**W=37.7 mm.**

## 2.2 Effective Dielectric Constant

An effective dielectric constant is given as

$$\varepsilon\text{reff} = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

εr=4.4, h=1.6mm, W=37.7mm

εreff=3.99

## 2.3 Length of Patch (L)

c=3*10^11 mm/s, εreff=3.99, f o=2.4GHz

Leff =30.25 mm

$$\Delta L = 0.412h\frac{(\varepsilon\text{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon\text{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

W=37.7 mm, h, =1.6mm, εreff=3.99

ΔL=0.70mm

**L= Leff-2ΔL=28.8 mm**

For the microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6 mm.

## 2.4 Substrate Dimension

For this design this substrate dimension would be

Ls=L+2*6h=50mm

Ws=W+2*6h=59mm

By increasing slot length the bandwidth increases. When we increase the length of the feed patch to 6 mm we get maximum bandwidth. The change in width of patch and slot is negligible. The air gap between the fed patch and the ground plays an important role in getting wide BW.

With increase in the air gap h, the total height of the antenna increases, and the effective dielectric constant experienced by the top patch reduces. Both of these factors increase the BW. The air gap height is 11mm.By introducing air gap bandwidth is increases.

**Table 1: Optimized parameters of antenna**

| Parameter | Value(mm) |
|---|---|
| W | 40 |
| L | 28 |
| W1 slot length | 3 |
| W2 slot width | 15 |
| Feed position(from patch) | 0.5 |
| Capacitive patch length | 6 |
| Capacitive patch width | 4 |
| Air gap height | 11 |
| Substrate height | 1.6 |
| Substrate / ground width | 55 |
| substrate / ground length | 60 |

# 3. SIMULATED RESULTS

## 3.1 Return Loss

It indicates the amount of power that is lost to load and does not return as reflection. Return loss is a parameter similar to VSWR to indicate how well the matching between transmitter and antenna has taken place. Ideal value of return loss is around 10dB which corresponds to VSWR of less than 2. “Figure 2” shows return loss of less than -10 dB for frequency range 2.275-2.905 GHz.

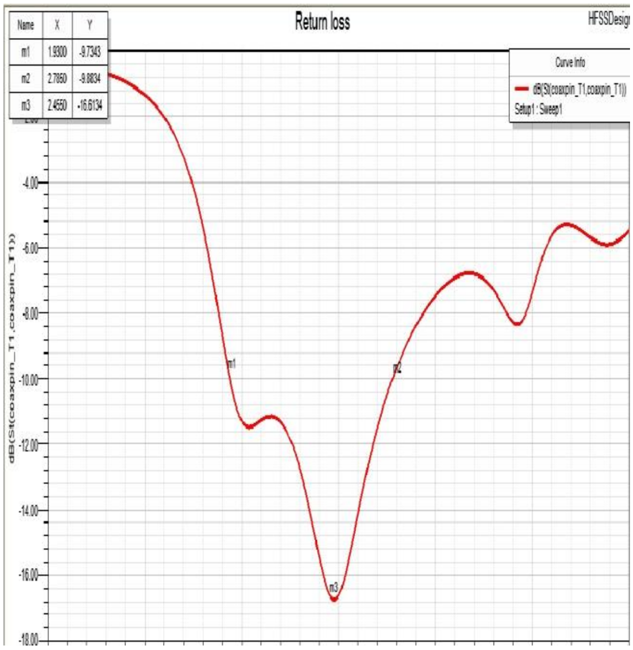


**Fig 2: Return Loss vs. Frequency**

## 3.2 VSWR

VSWR is a measure of how well matched an antenna is to the cable impedance. A perfectly matched antenna would have a VSWR of 1:1. This ratio indicates how much power is reflected back or transferred into a cable. VSWR is closely related to S11.The impedance set to 50 Ω for perfect impedance matching. “Figure 3” shows the obtained bandwidth is 630 MHz (26.25%).The VSWR <=2 for obtained bandwidth.

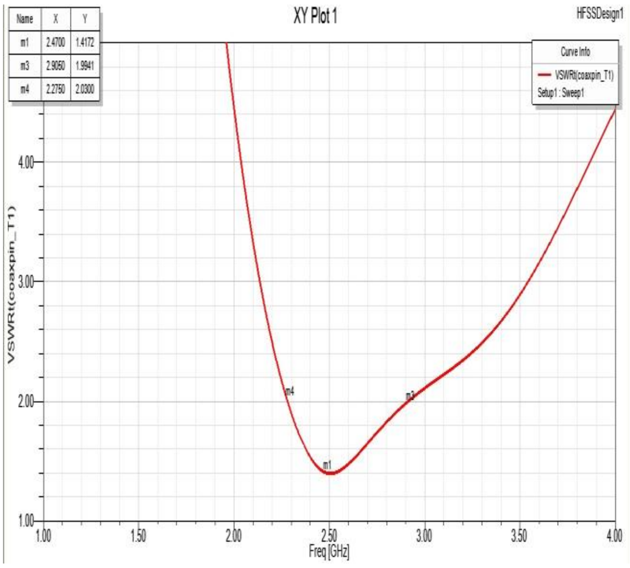


**Fig 3: VSWR vs. Frequency**

## 3.3 Radiation Pattern

Since a microstrip patch antenna radiates normal to its patch surface, the elevation for Eθ = 0° (zero degree) and Eφ = 90° would be important. Fig.4 below shows the maximum radiation occurs with gain of 3.24 dB. The radiation pattern shows that antenna radiates in particular direction.

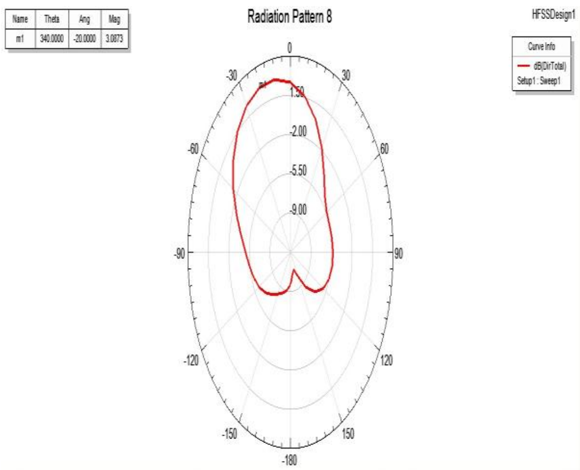


**Fig 4: Radiation Pattern**

# 4. CAPACITIVE FED WITH ELECTROMAGNETIC COUPLING MSA

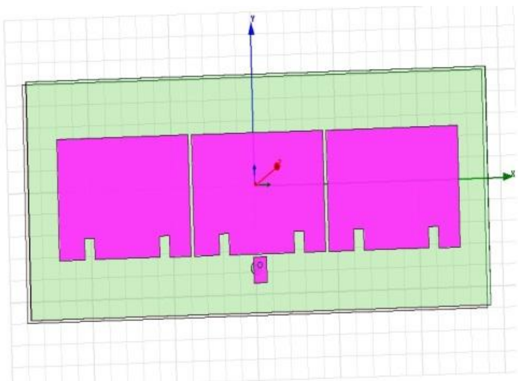

**Fig 5: ECMSA**

"Figure 5 shows" designed ECMSA in HFSS software. The above antenna is designed with parameters mentioned in Table 2. The antenna bandwidth can be improved by controlling the following antenna parameters the width (W) and length (L) of the patch, the height between the feeding line and the patch element, the height of the air gap, and the dimensions of the ground plane and substrate.

It is fabricated on 1.6 mm thick FR4 substrate. The length and width of dielectric substrates are 140 mm & 55 mm. The conducting ground plane is rectangular in shape with dimensions 140 mm length & 55 mm width. The patch is E shaped with dimensions W & L mentioned in Table 2 .The feed patch length is 6mm and width is 4 mm. It is 0.5 mm away from middle patch. The distance between ground and substrate is 11mm.

**Table 2 Optimized parameters of antenna**

| Parameter | Value (mm) |
|---|---|
| W | 40 |
| L | 28 |
| W1 slot length | 3 |
| W2 slot width | 15 |
| Feed position(from patch) | 0.5 |
| Capacitive patch length | 6 |
| Capacitive patch width | 4 |
| Air gap height | 11 |
| Substrate height | 1.6 |
| Substrate / ground width | 55 |
| substrate / ground length | 140 |

**Fig 6: Fabricated ECMSA**

This fabricated antenna is connected to vector analyser using SMA connector. The results such as Return Loss, VSWR can be seen on analyser.

# 5. RESULTS

## 5.1 Return Loss

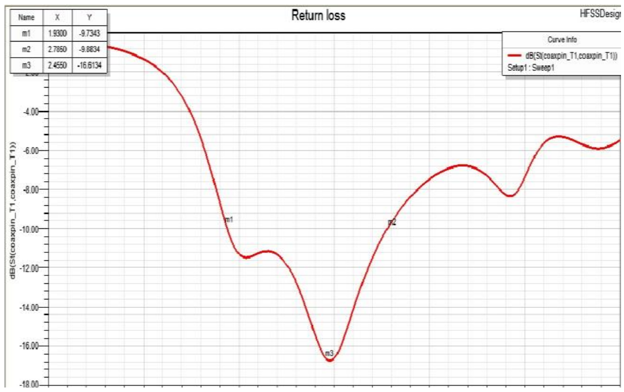


**Fig 7: Return Loss Vs. Frequency**

"Figure 7" shows Return loss variation with respect to frequency of the antenna. The minimum return loss for satisfactory operation of antenna is -10dB.The obtained return loss by simulation is -16.49 db.

## 5.2 VSWR

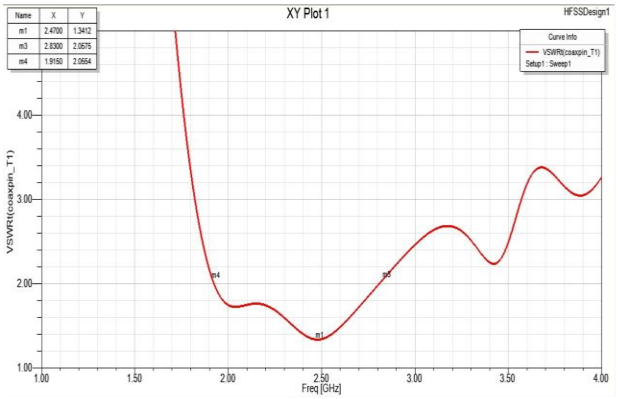


**Fig 8: VSWR VS Frequency**

"Figure 8" shows VSWR variation with respect to frequency of antenna. VSWR obtained by simulation is1.347 at centre frequency 2.47 GHz. It is less than 2 for frequency range 1.915-2.83 GHz.

Capacitive fed with electromagnetic coupling MSA antenna works on frequency range 1.915-2.83GHz. The obtained bandwidth is 915 MHz (38.12%).

## 5.3 Radiation Pattern

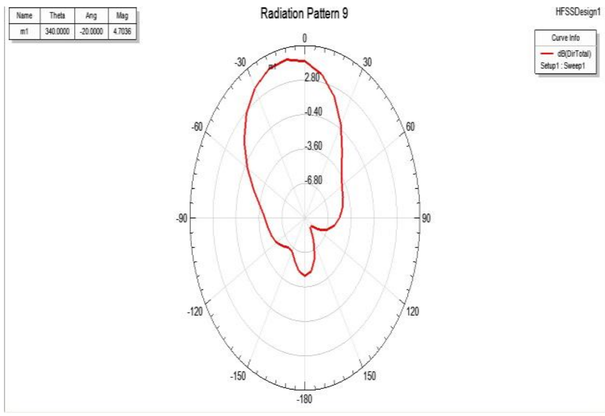


**Fig 9: Radiation Pattern**

"Figure 9" shows radiation pattern. The pattern obtained is directional. Antenna radiates only in particular direction with gain of 4.8db. The antenna is directional antenna hence radiates in one direction only.

**Table 3. Comparisons of simulated results of Capacitive fed MSA & Capacitive fed with coupling MSA**

| Sr. No | Antenna techniques | Bandwidth (MHZ) | Gain (dB) |
|---|---|---|---|
| 1. | Capacitive fed MSA | 630 (26.25%) | 3.24 |
| 2. | Capacitive fed with coupling MSA | 915 (38.12%) | 5.07 |

Table No.3 shows the simulation results of designed antenna. Capacitive fed with ECMSA gives highest bandwidth i.e. 915 (38.12%) MHz Suspended E shape gives 300 MHz (12.1%) bandwidth. Capacitive fed MSA provides 630 MHz bandwidth but gain obtained by this method is very less i.e.3.24 db.

## 6. CONCLUSION

In this paper antenna is designed for wideband applications. The work started with E shaped Capacitive fed MSA with resonant frequency 2.4 GHz provides 630 MHz bandwidth. To improve the bandwidth of this antenna, modified ECMSA is designed which results in to bandwidth of 915 MHz (38.12%) and gains of 5.07 db. Thus simulation results show the enhancement of bandwidth obtained by ECMSA than capacitive fed MSA.

It is also observed that the size of MSA is increasing due to suspended MSA techniques. We would like to look at how decrease the size of design at the frequency on different patches shapes adding of a shorting wall between the conducting patch and the ground plane, and the addition of a shorting pin between the conducting patch and the ground plane

## 7. REFERENCES

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