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# Broadband Stacked Electromagnetically Coupled Circular Microstrip Antenna

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***Abstract:*** *This paper presents simulation results for broadband stacked circular microstrip antenna. The centre frequency chosen for the antenna design is 2.1 GHz. FR4 and air is used as substrate. Single circular patch is simulated using FR4 as substrate, which gives bandwidth of around 2.4%. Patch with same dimensions is simulated at a height h = 5mm using air as substrate, which gives increased bandwidth and gain. One bottom one top (1B1T) configuration gives higher bandwidth and gain of approximately 16.67% and 10.1dBi respectively.*

***Keywords:*** *Bandwidth, Electromagnetically coupled, Gain*.

## I. Introduction

Microstrip antennas (MSA) are most widely used antenna because of its several advantages like, low cost, low volume, light weight, and planar configuration etc. It has some disadvantages too like narrow bandwidth and lower gain [1]. The bandwidth of MSA can be increased by using thicker substrate with low dielectric constant [2]. This gives about 10% increment in bandwidth. The bandwidth can be improved by using many techniques such as gap coupled [3], electromagnetically coupled [4] and stacking patch antennas with air layer or foam layer between stacked patches [5]. There are various shapes of MSA available. In the present work circular microstrip antenna (CMSA) is used. CMSA gives wide bandwidth and high gain [6].

Broad bandwidth is obtained by stacking two or more patches which are electromagnetically coupled [7]. In present work single patch is designed on FR4 substrate which has height of 1.6 mm and dielectric constant of 4.4. It gives bandwidth of 2.38% which is quite less. So, as discussed above thicker substrate with low dielectric constant increases the bandwidth, same circular patch is designed using air substrate with increased height h = 5mm and dielectric constant of 1. This configuration gives increased bandwidth and gain. For further increment in bandwidth and gain these two patches are stacked called as one bottom one top (1B1T) configuration. In 1B1T only bottom patch is fed, and upper patch is electromagnetically coupled to lower patch.

## II. Design Equation

For FR4 substrate $\varepsilon_r = 4.4$, $h$ =1.6mm.
Centre frequency $f_0$ = 2.1 GHz

**a) Wavelength at center frequency**

$$\lambda_0 = \frac{c}{f_o} = 142.85\text{mm}$$

**b) Height for air substrate**

Height of the antenna can be increased at a certain point because it may lead to increase in the power loss on the surface waves. The loss due to surface wave can be neglected when *h* satisfies the following criterion [2,8]

$$h \le \frac{0.3\,\lambda_0}{2\pi\sqrt{\varepsilon_r}}$$

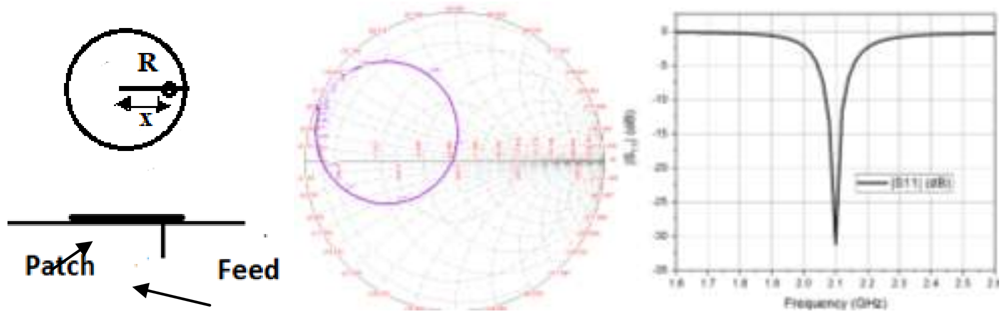
Substituting $\varepsilon_r = 1$ in the criterion, $h \le 6.82$mm is obtained for air substrate. In the proposed antenna design, optimized height $h$ = 5mm is taken which is close to above criterion.

## III. Antenna Geometry

In the present work, different configurations of circular patch are analyzed for broadband operation using IE3D Zeland Software.

**A. Single circular patch using FR4 substrate**

With the help of approximate dimension calculated above, A single circular patch on FR4 substrate is designed as shown in fig.1 (a). To resonate patch at 2.1GHz the radius of patch R = 19.8 mm (0.138λ0) and feed at x = 7.5mm is analyzed. Fig. 1(b) shows the input impedance plot for single circular patch. As shown in fig.1(c) single patch gives the bandwidth ($|S_{11}|$<-10 dB) of 50MHz (2.38%) and gain of 2.5dBi at 2.1GHz frequency.

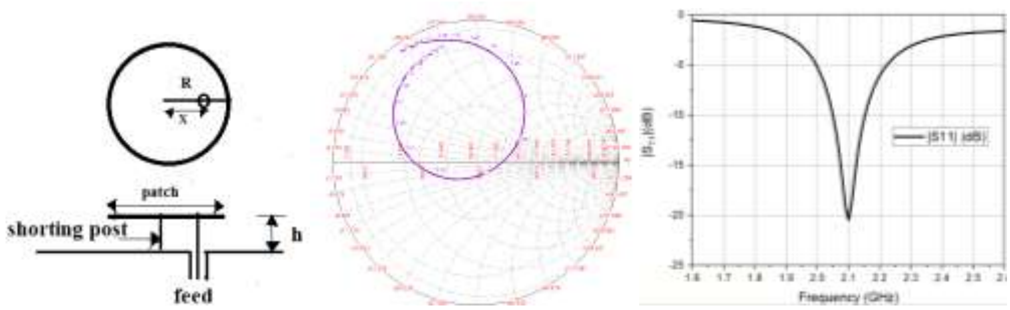



(a) (b) (c)

**Fig.1** single circular patch using FR4 substrate (a) top and side view (b) impedance plot (c) $|S_{11}|$ plot

**B. Single circular patch using air substrate**

To increase the bandwidth of an antenna single patch is analyzed using air substrate which has dielectric constant of 1. The patch is optimized at height h = 5mm to obtain wide bandwidth as shown in fig.2 (a). At the center of patch one shoring post is provided for support. To resonate patch at 2.1 GHz the radius of patch R = 37.5mm (0.262λ0) at feed point x = 13mm and the substrate height h = 5mm (0.034λ0) is taken. Fig.2 (b, c) shows the simulated input impedance plot and $|S_{11}|$ plot of single circular patch. The $|S_{11}|$ ≤ -10 dB bandwidth of 100 MHz (4.76%) and the gain of 9.5 dBi at 2.1GHz is obtained. The bandwidth increases by almost twice than that of single patch on FR4 substrate. Gain is also improved significantly.



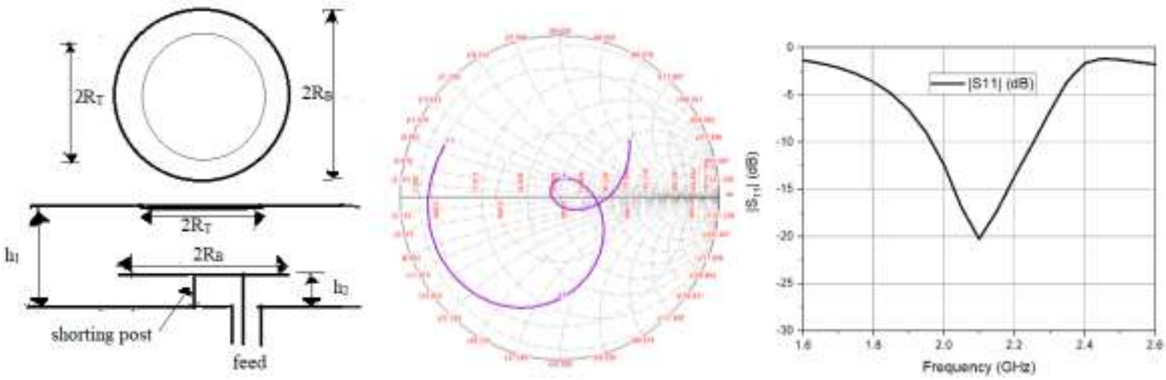

(a) (b) (c)

**Fig.2** single circular patch using air substrate (a) top and side view (b) impedance plot (c) |S11| plot

**C. One Bottom One Top configuration (1B1T)**

Thick substrate with minimum dielectric constant improves the bandwidth of MSA. But there is limitation on increasing the height of substrate as it increases the probe inductance. So, to overcome the problem, multiple resonator technique using microstrip patches can be used. In the proposed configuration a single circular patch is taken in both lower and upper layer with a bottom patch radius $R_B$ = 37mm (0.258λ0), and top patch radius $R_T$ = 28mm (0.195λ0). Only a bottom patch is fed by N-type connector with a feed point at x = 21mm and one shorting post is provided at the center of lower patch for support as show in fig.3 (a). The upper patch is designed on FR4 substrate whereas lower patch uses air as a substrate.

Simulation results of 1B1T are shown in Fig.3 (b, c) for the height between ground to bottom patch $h_2$= 5mm (0.034λ0) and height between ground to top patch $h_1$ = 13mm (0.09λ0) with ground plane size Lg = Wg = 190mm (1.328λ0).




(a) (b) (c)

**Fig.3** 1B1T configuration (a) top and side view (b) impedance plot (c) |S11| plot

1B1T configuration yields a bandwidth of 350 MHz (16.67%) and gain of around 10.1dBi at 2.1 GHz, which is comparatively more than single circular patch in both the case as discussed above.

## IV. Results

The performance of all these antennas is summarized in Table 1. Below configurations have wider bandwidth and simpler feed.

**Table 1.** Comparison of different circular patch configurations

| Sr. no. | Name | BW (MHz) | BW (%) | Gain (dBi) |
|---|---|---|---|---|
| 1 | Single circular patch using FR4 | 50 | 2.38 | 2.5 |
| 2 | Single circular patch using air | 100 | 4.76 | 9.5 |
| 3 | 1B1T | 350 | 16.67 | 10.1 |

## V. Conclusion

In this paper it is observed that bandwidth increases with the height of the antenna. Improved bandwidth is obtained using stacked electromagnetically coupled technique. Bandwidth and gain of 1B1T increases as compared to single circular patch using air and FR4 as substrate.

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