Development & Design of Stacked Microstrip Patch Antenna for Wireless Application

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Abstract— This project addresses the design of stacked microstrip patch antenna for wireless application. The proposed microstrip stack antenna has the operating frequency at 4GHz. The antenna is designed with FR-4 material as substrate that as the relative permittivity of 4.4 and loss tangent 0.02. The feeding technique used is microstrip feeding. The stacked microstrip antenna overcomes the limitations of normally narrowband microstrip antenna without altering the ground plane, which helps the antenna to achieve a unidirectional radiation pattern along with large bandwidth. The proposed antenna is suitable for various wireless applications. The proposed antenna is designed and simulated using HFSS (High Frequency Structural Simulator) software.

Key words: Microstrip Patch Antenna, Wireless Application

I. Introduction

Although a microstrip antenna has practical advantages, such as low profile and light weight, a single patch antenna has low gain (5–8dBi) and a narrow bandwidth. It is well known that a multilayer structure is a useful method to improve these problems. By stacking a parasitic patch on a fed patch, an antenna with high gain or wide bandwidth can be realized [8]. These characteristics of the stacked microstrip antenna depend on the distance between the fed patch and the parasitic patch. The microstrip antenna stacking a parasitic patch close to a fed patch has wide bandwidth, whereas the antenna stacking the parasitic patch at a spacing of approximately half a wavelength has high gain. Experimental studies [9–12] and theoretical studies [13–16] for the wide bandwidth approach have been reported. The Hankel transform [13, 14] and the spectrum domain method [15, 16] were applied to the stacked antennas. It has been reported that a stacked antenna with two patches spaced approximately half a wavelength apart has a high gain using numerical analysis with the wire grid model [17]. It has also been reported that an aperture-stacked patch microstrip antenna has a relative bandwidth of about 70%. The behavior of the antenna was explained in [18, 19]. Experimental investigation has shown that a stacked microstrip antenna has a high gain when the distance between the fed patch and the parasitic patch is 0.3–0.5l [20–22]. However, these studies are investigations into wide bandwidth or gain enhancement and are limited to the analysis of the resonant frequency, impedance and far field.

This paper describes the design and performance of a single-feed stacked arrangement of rectangular patches on a glass epoxy FR-4 substrate. The proposed antenna will radiate at three frequencies. A much improvement in gain has been achieved.

II. Antenna design & results

A. *Design Concept of Rectangular Microstrip Patch Antenna*

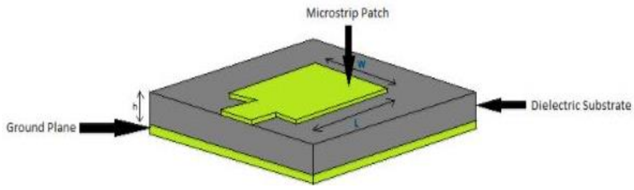

Fig. 1: Structure of Microstrip Patchb Antenna

Width of Rectangular Patch is calculated using equation

$$w = \frac{c_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1.1)$$

W - Width of the patch
c_0-Speed of light
ε_r-substrate dielectric constant
f_r- Frequency of Resonance
Length of Rectangular Patch is calculated using equation
Effective dielectric constant ε_{reff}

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-\frac{1}{2}} \quad (1.2)$$

Fringing effect of patch ΔL

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)} \quad (1.3)$$

Effective length L_{eff}

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \quad (1.4)$$

Rectangular Patch length

$$L = L_{eff} - 2\Delta \quad (1.5)$$

ε_r-substrate dielectric constant
h- Thickness of substrate material
f_r- Frequency of Resonance

B. *Single-Layer Rectangular Microstrip Antenna*

First, we have considered a single-layer rectangular patch antenna. This antenna is designed on a glass epoxy FR-4 substrate. The antenna is fed through a microstrip transmission line feed as shown in the fig 1(a). The dimensions of the antenna are listed in the table below. The simulation analysis of this antenna is carried out by HFSS (High Frequency Simulation Software). The fig 1(b) shows the return loss characteristics of the antenna. The proposed antenna resonates at 4GHz and gain of -2.69 is achieved as shown in the fig 1(c). Radiation pattern and VSWR also stimulated as shown in fig 1(d) and fig 1(e) respectively. The proposed antenna has the VSWR value as 2.5.

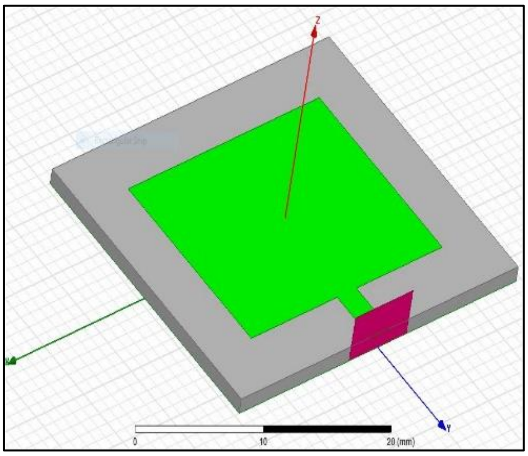

Fig. 2(a): Microstrip Patch Antenna with Single Layer

Parameters	Value(mm)
Substrate length Ls_1	24
Substrate width Ws_1	29
Patch length L_1	16
Patch width W2	21
Height h	1
Dielectric constant ε_{r1}	4.4

Table 1: Parameters & Dimensions of Single Stack Antenna

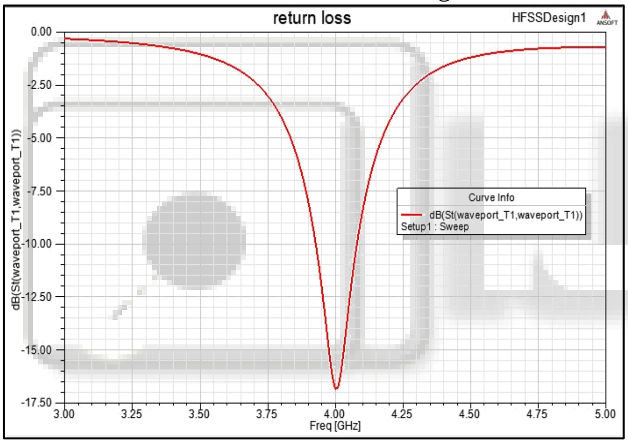

Fig. 2(b): Return Loss

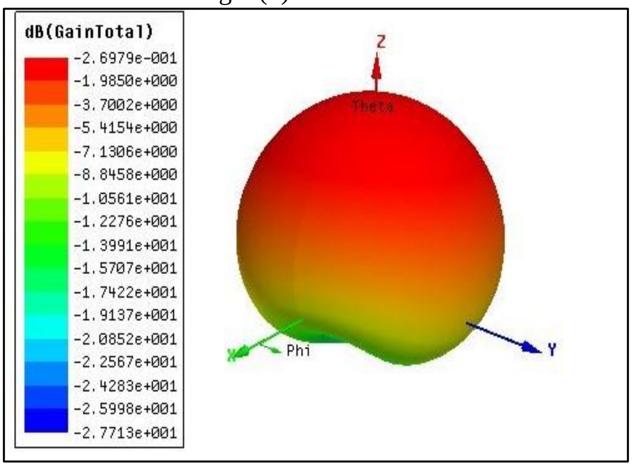

Fig. 2(c): Gain

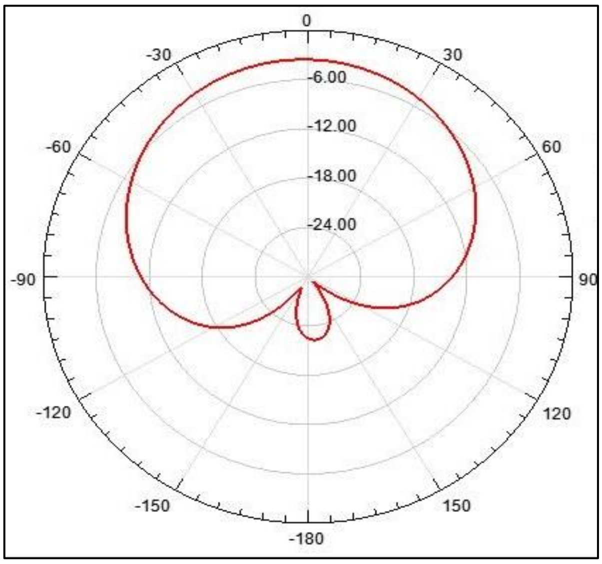

Fig. 2(d): Radiation Pattern

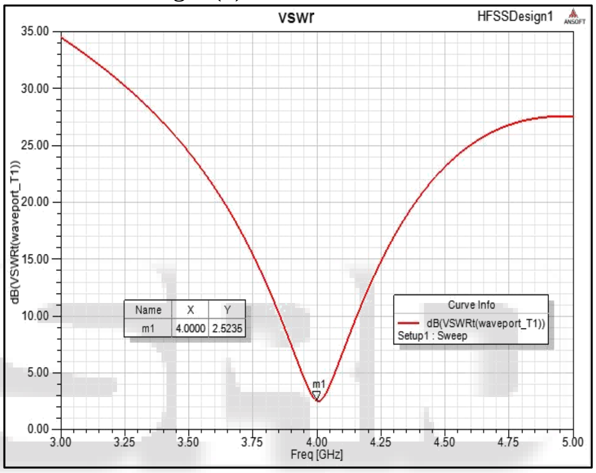

Fig. 2(e): VSWR

C. Double-Layer Rectangular Microstrip Antenna

We have considered a double-layer rectangular patch antenna. The antenna consists of two layers, one with driven patch (were the feed is given) and other with the parasitic patch placed above driven patch at a distance d=1mm. This antenna is designed on a glass epoxy FR-4 for both the substrate. The antenna is fed through a microstrip transmission line feed for the driven patch as shown in the fig 2(a). The dimensions of the antenna are listed in the table below. The simulation analysis of this antenna is carried out by HFSS (High Frequency Simulation Software). The fig 2(b) shows the return loss characteristics of the antenna. The proposed antenna resonates at 4.1GHz, 6.5GHz & 8.25GHz and gain of 4.66 is achieved as shown in the fig 2(c). Radiation pattern and VSWR also stimulated as shown in fig 2(d) and fig 2(e) respectively. The proposed antenna has the VSWR value as 0.39.

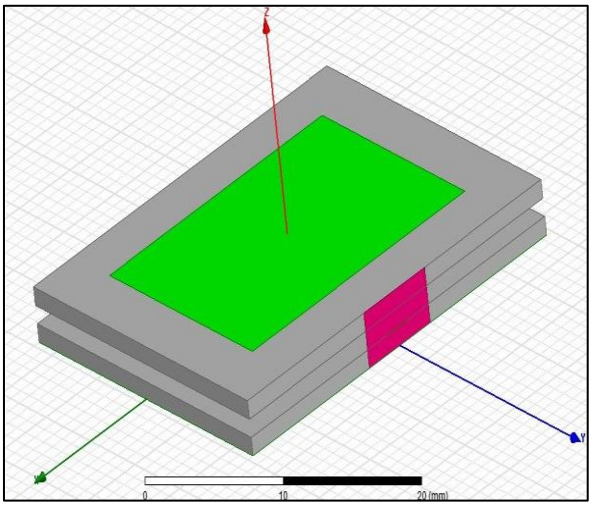

Fig. 3(a): Double Layer Microstrip Stack Antenna.

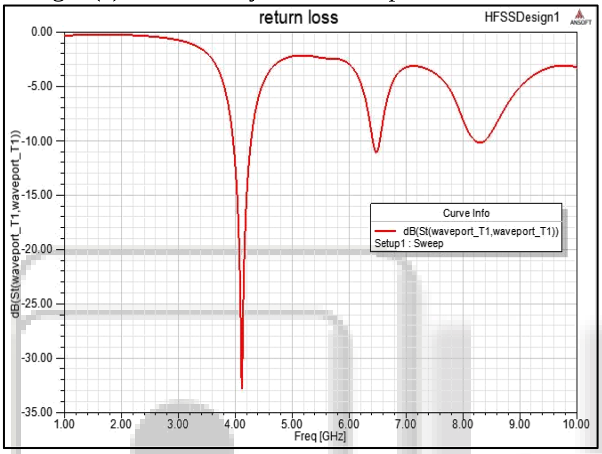

Fig. 3(b): Return Loss

Parameters	Value(mm)
Ls_2	24
Ws_2	29
L_2	16
W_2	21
h_2	1
εr_2	4.4
d	1

Table 2: Parameters & Dimensions of Double Stack Antenna

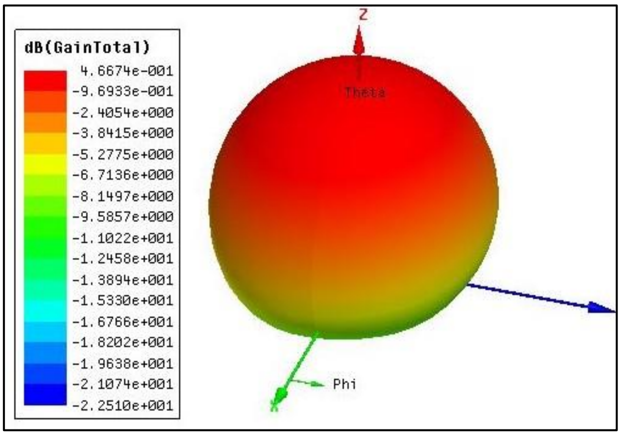

Fig. 3(c): Gain

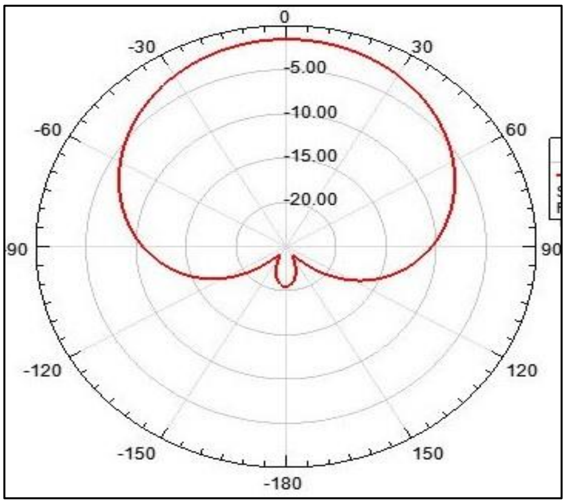

Fig. 3(d): Radiation Pattern

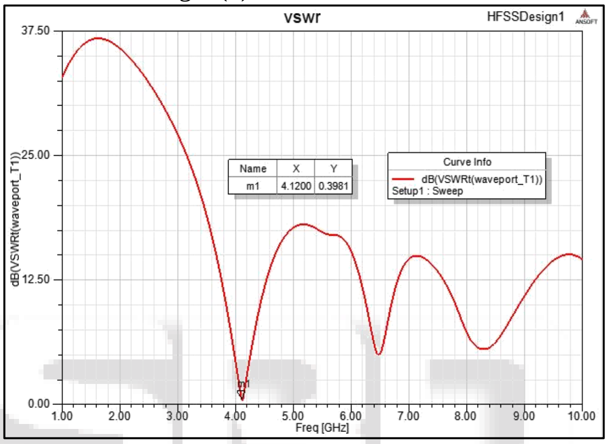

Fig. 3(e): VSWR

Parameter	Single layer	Double layer
S_{11}(dB)	-16.82	-32.80
Gain(dB)	-2.69	4.66
VSWR	2.5	0.39
Peak directivity	1.55	1.40
Radiated power(w)	0.0047	0.0077
Radiation efficiency	60.05%	74.43%
Front to Back ratio	74.91	75.08

Table 3: Comparison Between Single & Double Layer Stack Antenna

III. CONCLUSION

This letter presents the design and performance of a single-feed stacked arrangement of rectangular patches on a glass epoxy FR-4 substrate. The designed antenna presents much improved impedance and bandwidths and larger gain than a single-layer antenna. These improved parameters are achieved without much increase in the thickness of the structure. The significant improvement in the bandwidth is the main achievement of the proposed work.

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