*Journal of Physical Sciences, Vol. 18, 2014, pp. 89-97*
*ISSN: 0972-8791, www.vidyasagar.ac.in/journal*
*Published on 27th March 2014*

# A Novel Approach in Slotted Microstrip Patch Antenna Design for GSM 1800 MHz Band

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*Received on 24th February 2014; accepted on 25th March 2014*

**ABSTRACT**

In this paper a slotted Microstrip Patch Antenna has been designed and simulated in IE3D environment. FR4 substrate with an electrical permittivity of 4.4 has been chosen as the substrate material. Line feeding technique for conventional patch design has been replaced by Coaxial feeding technique. The incorporation of slots in the proposed structure have effectively reduced the patch surface area. Also there is a huge reduction in the required substrate height than conventional cases. The proposed structure showed promising results in perspective of return loss, gain, efficiency and directivity which are compared with the responses of conventional microstrip patches used for GSM 1800 MHz band.

***Keywords****: Microstrip Patch Antenna, Slot, Return loss, Gain, Efficiency, Directivity*

## 1. Introduction

A Microstrip Patch Antenna generally consists of a dielectric substrate sandwiched between a radiating patch on the top and a ground plane on the other side. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. For simplicity of analysis, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape.

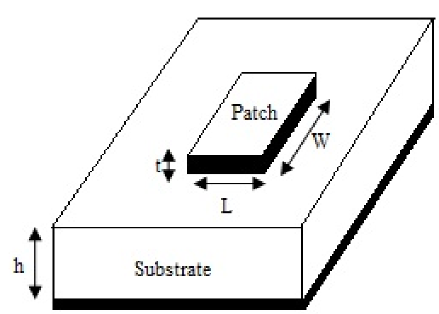


**Figure 1.** Microstrip Patch Antenna

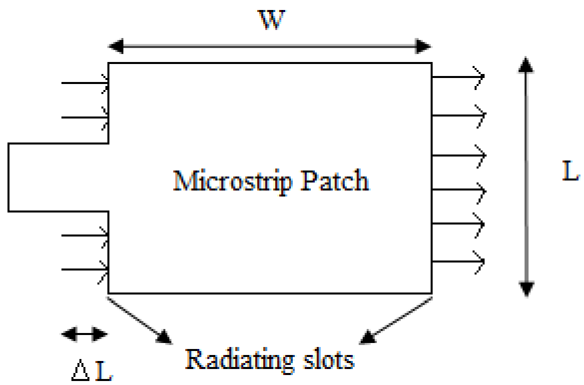


**Figure 2.** Top view of antenna

For a rectangular patch, the length L of the patch is usually in the range of 0.3333 $\lambda_o < L < 0.5\ \lambda_o$, where $\lambda_o$ is the free space wavelength. The patch is selected to be very thin such that $t \ll \lambda_o$ (where $t$ is the patch thickness). The height h of the substrate is usually $0.003\ \lambda_o \leq h \leq 0.05\ \lambda_o$. The dielectric constant of the substrate $\epsilon_r$ is typically in the range $2.2 \leq \epsilon_r \leq 12$. [3] An effective dielectric constant ($\epsilon_{reff}$) must be obtained in order to account for the fringing and the wave propagation in the line. The value of $\epsilon_{reff}$ is slightly less than $\epsilon_r$ because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in air.

The expression for $\epsilon_{reff}$ is given by [1] as,

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\sqrt{1+12\ h/W} \qquad (1)$$

where,

$\epsilon_{reff}$ = Effective Dielectric Constant
$\epsilon_r$ = Dielectric Constant of Substrate
h = Height of Substrate
W = Width of Patch

The fringing fields along the width can be modeled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance $\Delta L$, which is given empirically by [1] as:

$$\Delta L = 0.412\, h \frac{(\varepsilon reff+0.3)\,(W/h+0.264)}{(\varepsilon reff-0.258)\,(W/h+0.8)} \qquad (2)$$

The effective length of the patch Leff now becomes,

$$L_{eff} = \frac{c}{2\, fo \sqrt{\varepsilon reff}} \qquad (3)$$

where fo is the resonant frequency.
For a given resonant frequency $f_0$, the effective length is given by,

$$L_{eff} = L + 2\,\Delta L \qquad (4)$$

For a rectangular microstrip patch antenna, the resonant frequency for any TM mode is given by [1] as,

$$f_0 = \frac{c}{2\sqrt{\varepsilon reff}} \left[(m/L)^2 + (n/W)^2\right]^{1/2} \qquad (5)$$

where m and n are the modes along L and W respectively.

For effective radiation, the width W is given by [3] as,

$$W = \frac{c}{2\, fo \sqrt{(\varepsilon r+1)/2}} \qquad (6)$$

**2. Proposed Design**

Fig. 3. shows the proposed structure designed using IE3D software. [6] Dimensions are as shown in the figure.

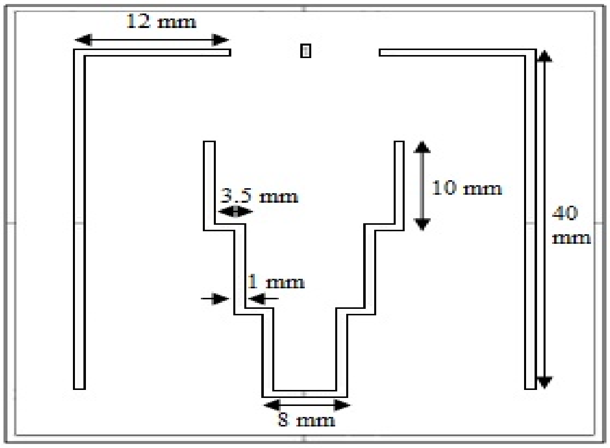


**Figure 3.** Proposed Patch Structure

Design Parameters:

- Length: 39.5 mm
- Width: 50.7 mm
- Substrate: FR4 ($\varepsilon_r$ : 4.4)
- Substrate height: 1.6 mm

### 3. Return Loss of proposed structure

Fig. 4. shows the Return Loss plot of the proposed patch.

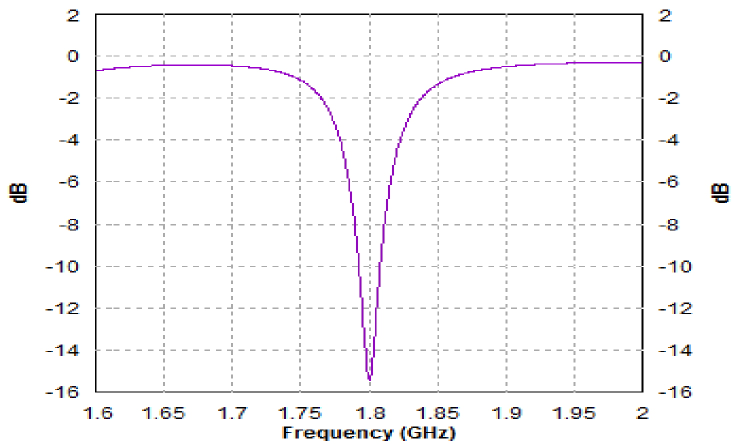


**Figure 4.** Return Loss ( $S_{11}$)

### 4. Conventional design

Fig. 5. shows the structure of a conventional patch designed in IE3D software environment.

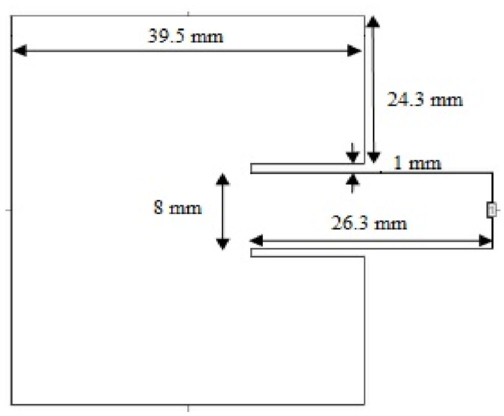


**Figure 5.** Conventional Patch Structure

Design Parameters:

- Length: 39.5 mm
- Width: 50.7 mm
- Substrate: FR4 ($\varepsilon_r$ : 4.4)
- Substrate height: 2.5 mm
- Feed length: 26.3 mm

**4. Results and Discussion**

*Return Loss*

$S_{11}$ is a measure of how much power is reflected back at the antenna port due to mismatch from the transmission line. . $S_{11}$ values are measured in dB and are negative, ex: -10 dB. $S_{11}$ is also sometimes referred to as Return Loss, which is simply $S_{11}$ but made positive instead (Return Loss = - $S_{11}$).

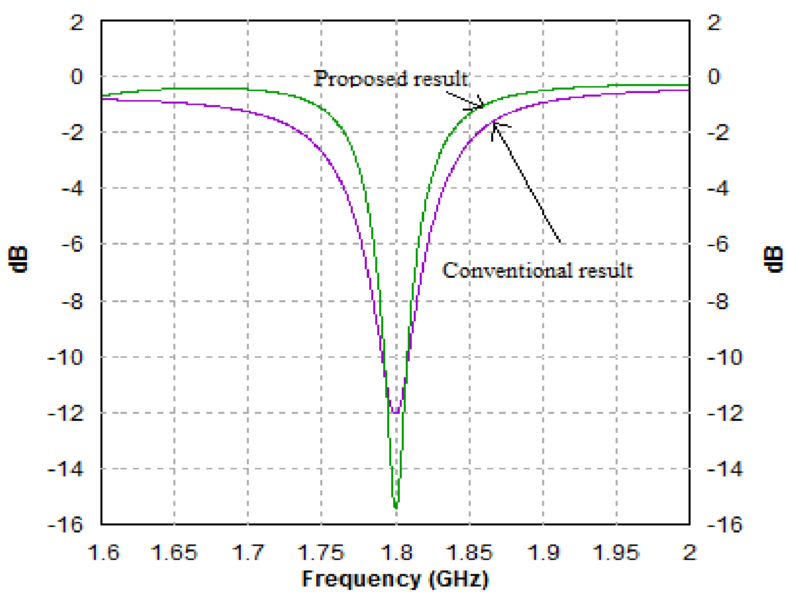


**Figure 6.** $S_{11}$ vs. Frequency

Fig. 6. shows the $S_{11}$ vs. Frequency comparison plot of the proposed patch shown in Fig. 3. and the conventional one shown in Fig. 5. Max. Return Loss is obtained in case of the proposed patch which is 15 dB (Reflection Loss: 0.14) whereas it is equal to 12 dB (Reflection Loss: 0.28) for the conventional one.

*Gain*

Antenna gain is usually defined as the ratio of the power produced by the antenna from a far-field source on the antenna's beam axis to the power produced by a hypothetical lossless isotropic antenna, which is equally sensitive to signals from all directions. Power gain is a unit less measure that combines an antenna's efficiency η and directivity D,

$$G = \eta \, . \, D \tag{7}$$

Fig. 7**.** shows the Gain vs. Frequency comparison plot of the proposed patch shown in Fig. 3. and the conventional one shown in Fig. 5. The conventional patch gain is less than 2 dBi whereas it is almost equal to 2.3 dBi for the proposed design.

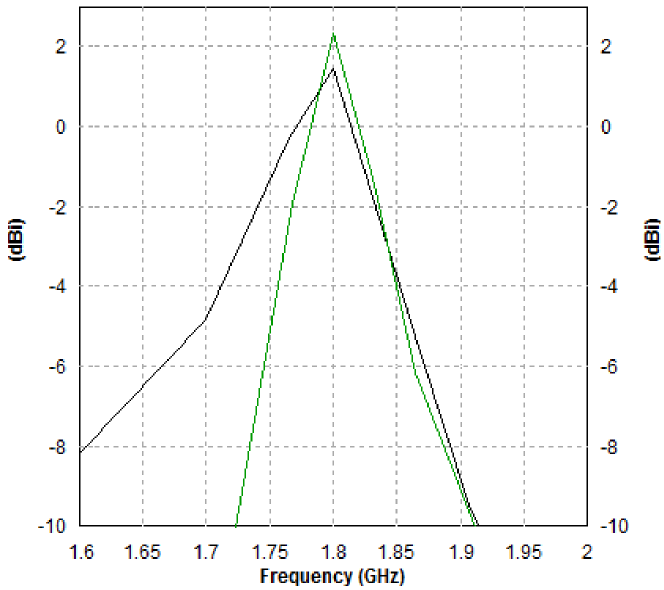


**Figure 7.** Gain vs. Frequency

*Efficiency*

Antenna efficiency η is a measure of the efficiency with which a radio antenna converts the radio-frequency power accepted at its terminals into radiated power. The efficiency of an antenna relates the power delivered to the antenna and the power radiated or dissipated within the antenna. Efficiency is very often quoted in terms of a percentage. **Fig. 8.** shows the Efficiency vs. Frequency comparison plots of the patches. The conventional patch efficiency is 31% whereas it is almost equal to 34% for the proposed patch structure.

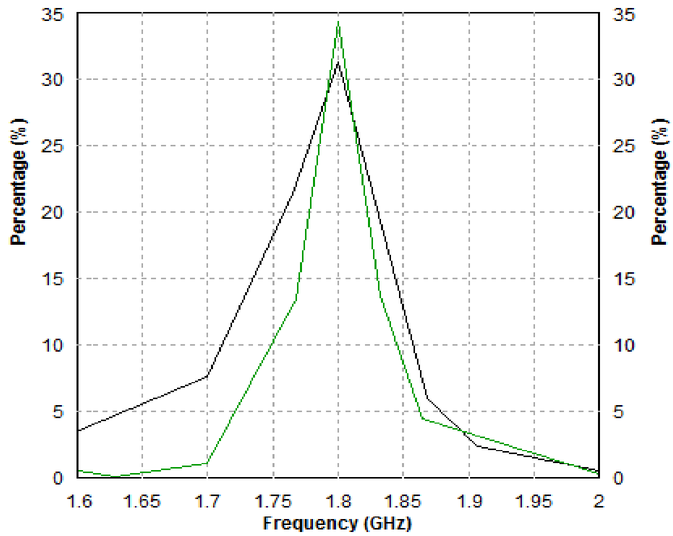


**Figure 8.** Efficiency vs. Frequency

*Directivity*

Directivity of an antenna is a measure of how 'directional' an antenna's radiation pattern is. It measures the power density the antenna radiates in the direction of its strongest emission, versus the power density radiated by an ideal isotropic radiator radiating the same total power. From Fig. 9**,** it is equal to 7.29 dBi for the proposed structure whereas it is down to 6.28 dBi for the conventional one.

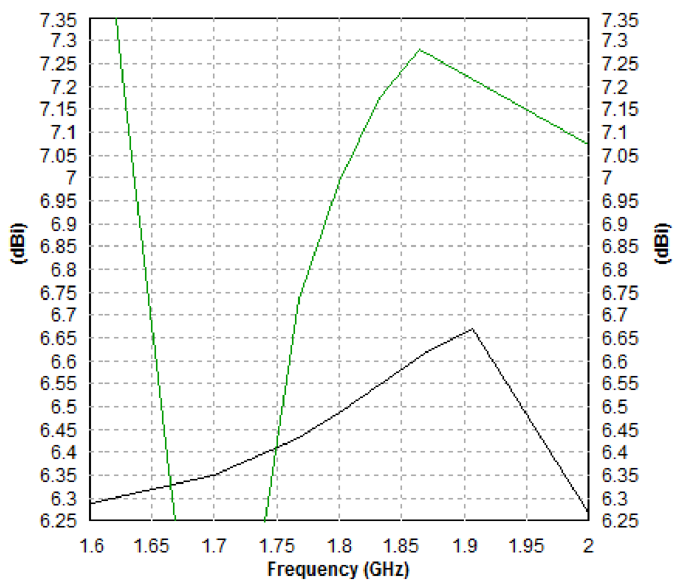


**Figure 9.** Directivity vs. Frequency

*Elevation Pattern Gain Display*

The elevation plane patterns are derived by simply slicing through the 3D radiation pattern. In this case, the elevation plane pattern is formed by slicing through the y-z plane. Fig. 10. shows the Elevation Pattern Gain Display of the conventional patch.

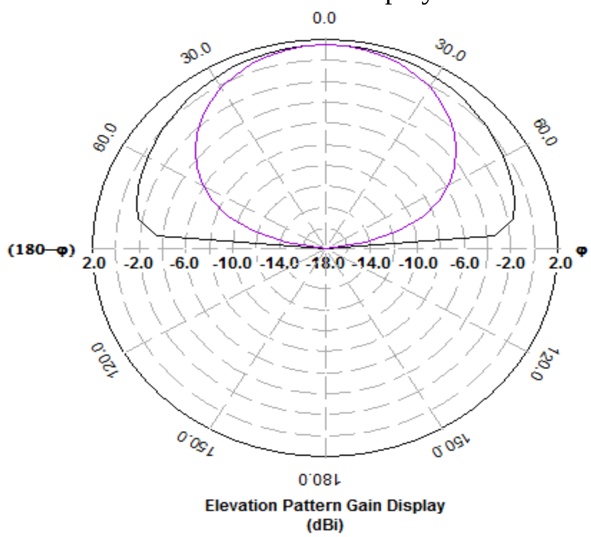


**Figure 10.** Elevation Pattern Gain Display (conventional)

Fig. 11 shows the Elevation Pattern Gain Display of the proposed patch antenna.

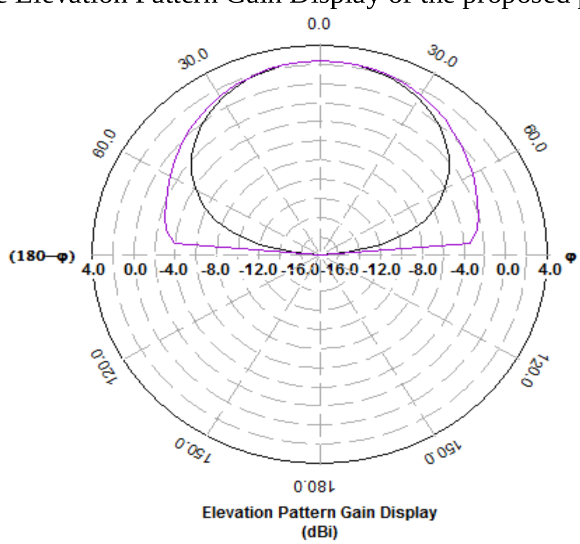


**Figure 11.** Elevation Pattern Gain Display (proposed)

**----** E-Total, phi = 0 deg.
**----** E-Total, phi = 90 deg.

## 5. Conclusion

A microstrip patch antenna is a low profile antenna that has a number of advantages over other antennas it is lightweight, inexpensive and easy to be integrated with accompanying electronics**.** The inclusion of slots have reduced the patch surface area by approximately 10%. Also the substrate height is effectively reduced by almost 1 mm. The proposed patch showed promising results in perspective of return loss, gain, efficiency and directivity which is better than conventional cases. Therefore the patch is practically suitable to be incorporated in mobile devices which support the GSM 1800 MHz band for communication purpose.

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