# COMPUTER AIDED DESIGN OF TRIANGULAR MICROSTRIP PATCH ANTENNA IN MULTILAYERED MEDIA 

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#### Abstract

In this paper, we propose a simple computer aided design (CAD) of the multilayered equilateral triangular patch (METP) based on cavity model analysis. The aim is to develop a simple closed form expression to accurately estimate the operating frequency of a coax-fed METP with a wide range of variations of the dielectric layers. The multilayered geometry comprises of an equilateral triangular patch sandwiched between two layers of dielectrics, lower one being the substrate and upper one, the superstrate. The theory is compared with the measured results and excellent agreement is revealed. The proposed CAD model is simple, accurate and thus should help a designer for practical applications.


## INTRODUCTION

The microstrip antennas are widely used in microwave and millimeter wave applications starting from satellite to mobile hand sets due to its low profile, light weight, and various other advantages. Of various shapes of microstrip patches, the triangular patch shows only a few handful investigations though this geometry is highly suitable for being etched on curved surfaces and also for designing a compact array. Triangular microstrip patch covered with a dielectric superstrate could be another potential candidate to be investigated from the application point of view. The dielectric cover (superstrate) acts as a radome and protects the patch from environmental hazards. Moreover, this provides an advantage of using this to achieve frequency agility and gain enhancement. The inherent characteristics of narrow impedance bandwidth of the triangular patch restrict its use in some cases and also appear as advantages forms in many other applications. Hence the accurate prediction of both the resonant frequency and input impedance becomes more essential for its efficient design. Very few studies on METP antenna have been reported so far. To the best of the knowledge of the authors, one full wave analysis is available in open literature [1].

In this paper, we propose a simple computer aided design of the METP based on cavity model analysis. The aim is to develop a simple closed form expression to accurately estimate the operating frequency of an METP with a wide range of variations of the dielectric layers. The multilayered geometry comprises of an equilateral triangular patch sandwiched between two layers of dielectrics, lower one being the substrate and upper one the superstrate. The patch is excited by a coaxial probe. The dielectric layer on top of the microstrip patch causes the change in the fringing fields between the patch and the ground plane. In this analysis, this effect has been accounted for in terms of the effective relative permittivity $\varepsilon_{r, ~ e f f ~}$ of the medium below the patch. The parameter $\varepsilon_{r, \text { eff }}$ is evaluated from the formulations derived in [2]

The theory is compared with the measured results available in the literature and excellent agreement is revealed. The computed values generated using this theory for different substrate-superstrate combinations are also compared with the theoretical values obtained from full wave spectral domain technique [1].

## THEORY

Following the cavity model analysis by Helszajn [3], a simple and more general expression for the resonant frequencies of $\mathrm{TM}_{\mathrm{nml}}$ modes of an equilateral triangular microstrip patch antenna with and with out air gaps can be given as

$$
\begin{equation*}
f_{r, n m}=\frac{2 c}{3 r_{e f f} \sqrt{\varepsilon_{r, e f f}}}\left(n^{2}+n m+m^{2}\right)^{1 / 2} \tag{1}
\end{equation*}
$$

where $c$ is the velocity of light in free space, $r_{\text {eff }}$ is the effective side length of the ETMP in presence of a dielectric superstrate and $\varepsilon_{r, \text { eff }}$ is the effective relative permittivity of the medium below the patch.

One or more dielectric layers above a microstrip patch cause the change in the fringing fields between the patch and the ground plane and that effect is accounted for by the effective relative permittivity $\varepsilon_{r, e f f}$. The general formulations obtained for a circular patch [2] which can be extended to calculate $\varepsilon_{r, e f f}$ for a triangular patch sandwiched between two dielectric layers (Fig.1) using the formulation

$$
\begin{align*}
& a=3 r / 2 \pi  \tag{2}\\
& r_{e f f}=(2 \pi / 3) * a_{e f f} \tag{3}
\end{align*}
$$

Equation (2) is derived from an equivalence relation between a circular patch (radius $=a$ ) and a triangular patch with side length $r$. Equal circumference was considered as the basis of equivalence to account for equal static fringing fields.

## RESULTS

Figure 2 shows the variation of the resonant frequency for the dominant $\mathrm{TM}_{10}$ mode with the change in the side length of an equilateral triangular microstrip patch antenna. The present model is compared with the measurement done by [1] for an antenna without any superstrate ( $h_{2}=0$ ). The present model shows close agreement between the theory and the measurement.

The plot shown in figure 3, depicts the variation of the resonant frequency for the change in superstrate thickness of an equilateral triangular microstrip patch covered with a dielectric superstrate. The measured datum [1] shows good correspondence with the present theory while the deviation from a more rigorous mathematical model proposed by [1] is apparent from the plot.

Table 1 shows the variation of the $\mathrm{TM}_{10}$ mode resonant frequency with the change in superstrate for an METP antenna. The present model is compared with the full wave spectral domain results [1].

## CONCLUSION

A simple closed form expression for estimating the resonant frequency of a multilayered triangular patch is proposed. The theory is compared with the measured results and excellent agreement is revealed. The computed values for different substrate-superstrate combinations are also compared with another full wave spectral domain analysis. The antenna geometry without the superstrate degenerates to a conventional triangular microstrip patch and the present model can also be extended to predict accurate values for that geometry also. The proposed CAD model is simple, accurate and easy to develop a code for a PC and thus should help the designers/ engineers for practical applications.

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## REFERENCES

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Fig. 1. Cross-sectional view of an Equilateral Triangular Microstrip Patch antenna in a Multi-layered Media


Fig. 2. Computed and measured resonant frequencies versus varying sidelength of an equilateral triangular patch antenna without any superstrate. $h_{l}=1.59 \mathrm{~mm}, h_{2}=0 \mathrm{~mm}, \varepsilon_{l}=2.5$


Fig. 3. Computed and measured resonant frequencies versus varying superstrate thickness of an equilateral triangular patch antenna covered with a dielectric superstrate. $r=37 \mathrm{~mm}, h_{l}=1.59 \mathrm{~mm}, \varepsilon_{r l}=2.5, \varepsilon_{2}=2.5$

## TABLE I

Comparison of Resonant Frequencies with the Variation of Superstrate Dielectric Constant of a Multilayered Equilateral Triangular Microstrip Patch Antenna.

Parameters: $\varepsilon_{l}=2.5, r=37 \mathrm{~mm}, h_{l}=h_{2}=1.59 \mathrm{~mm}$

| $\varepsilon_{2}$ | Present | SDA [1] |
| :---: | :---: | :---: |
|  | 3.156 | 3.30 |
| 1.0 | 3.133 | 3.245 |
| 1.5 | 3.0955 | 3.165 |
| 2.5 | 3.0712 | 3.12 |
| 3.2 |  |  |

