xqrAs per UGC guidelines an electronic bar code is provided to seure your paper

*International Journal for Modern Trends in Science and Technology*
*Volume 10, Issue 03*, pages 198-202.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol10issue03.html
DOI: https://doi.org/10.46501/IJMTST1003032

# Analyze and Design Dual band Elliptical microstrip Patch antenna

**R. Jagadeesh Chandra Prasad[1], Dr. J Rajeshwar Goud[1], Dr. Devika S V[1], Dr. Arvind S[2]**

[1]Department of ECE, Hyderabad Institute of Technology and Management, Hyderabad, India
[2]Department of CSE, Hyderabad Institute of Technology and Management, Hyderabad, India

**To Cite this Article**
R. Jagadeesh Chandra Prasad, Dr. J Rajeshwar Goud, Dr. Devika S V, Dr. Arvind S, Analyze and Design Dual band Elliptical microstrip Patch antenna, International Journal for Modern Trends in Science and Technology, 2024, 10(03), pages. 198-202.https://doi.org/10.46501/IJMTST1003032

**Article Info**
Received: 02 February 2024; Accepted: 26 February 2024; Published: 03 March 2024.

## ABSTRACT

*The paper describes a simple approach for precisely determining the resonance frequency of an elliptical microstrip patch made from isotropic or anisotropic substrate materials. This method accounts for fringe fields, dispersion effects, and losses by calculating effective dimensions, anisotropic permittivity in the layer, and effective loss tangent. The theoretical resonant frequency results agree with previously reported experimental results. According to numerical calculations, a little disturbance in the substrate has the greatest effect on the antenna's resonance frequency. Uniaxial anisotropic materials are essential for characterizing microstrip antennas. Antenna was designed in HFSS /Ansys and the antenna resonated at dual frequency 3.5GHZ and 5GHz.*

*Keywords: Elliptical-disk antenna, Anisotropic substrate, Cavity method, Fringe fields, Circular polarizations*

## 1. INTRODUCTION

Microstrip antennas are widely employed in high-performance aircraft, spacecraft, satellites, and other applications due to their low profile, conformability to planar and non-planar surfaces, and low manufacturing costs [1-3]. Research prospects are increased by antenna shape choices [4]. There is a lot of content available on both circular and rectangular shapes. These geometries aren't suitable for every application, though [5]. Traditional microstrip antennas are round or rectangular, and they transmit linear polarization at a single resonance frequency. Circular polarizations (CPs) and dual-resonant frequencies are frequently used for navigation, radar, and communication systems [6]. Patch arrangements are used on a variety of substrates. We looked at and investigated a number of patch configurations on various substrates. Optimizing antenna radiation qualities requires selecting the appropriate substrate material [7, 8].

The elliptical patch has undergone substantial analysis using many models, including the cavity model [4, 10-12], the generalized transmission line model [13, 14], and the Fourier-Hankel transform domain [5]. The method of moments (MoM) [14], other full-wave studies [10, 15], and commercial software do not offer closed-form expressions and require significant processing effort. Full-wave analysis and commercial tools are not suitable for direct synthesis of patch antennas. The CAD-oriented cavity model is suitable for design. Another advantage of the proposed mode is that it takes into account the uniaxial anisotropy in the substrate. The cavity model has been chosen as a simple alternative to analyze and predict the behavior of elliptical microstrip antennas (EMAs). Furthermore, some modifications are made to account for fringe fields, dispersion effects, and losses by calculating effective dimensions, effective relative permittivity, and effective loss tangent, respectively. However, the effect of uniaxial anisotropy in the substrate on the dual-resonant frequency of elliptical patch microstrip antenna for different structural parameter cases have been not included in the open literature.

However, we are interested in this work to study the effects of anisotropic substrate materials on the resonant frequency of an elliptical patch antenna. Moreover the study of this type of substrates is of interest, many practical substrates have a significant amount of anisotropy that can affect the performance of printed circuits and antennas, and thus accurate characterization and design must account for this effect [8]. It is shown that formulation provides accurate results within lower percentage error values with respect to the previous analyses. Thus, it can be used confidently for the determination of the effect of anisotropic substrate materials on the dual-resonant frequency of an elliptical patch antenna. The proposed model does not require any complicated mathematical functions. This is very simple, efficient, accurate and suitable for CAD applications to design wide bandwidth and high gain antenna for wireless communication.

## 2. ANTENNA CONFIGURATION AND DESIGN

The geometrical configuration of EMA for obtaining the dual resonant frequency $f_{11}^{e,o}$ and circular polarizations (CPs), consists of a planar slightly elliptical patch with the semimajor axis a and the semi-minor axis b, elliptical patch is parallel to ground plane and separated from ground plane by a dielectric substrate with relative permittivity 1r and height  as shown in Fig. 1.

The resonant frequency of elliptical waveguide [6] can bemodified and simplified for our case to yield

$$f_{11}^{e,o} = \frac{15}{\pi e a}\sqrt{\frac{q_{11}^{e,o}}{\varepsilon_r}}, \tag{1}$$

where $f_{11}^{e,o}$ is the dual-resonant frequency of even $TM_{11}^{e}$, and odd $TM_{11}^{0}$ , mode and a is the physical semi-major axis.

Generally, the measured results of the $f_{11}^{e,o}$ are lower than themmcalculated values due to the effective (electrical) semi-major axis $a_{ef}$ ($a_{ef}$>a). The parameter $a_{ef}$is used to account for the stored energy in the fringing field of elliptical edge. Therefore, $f_{11}^{e,o}$ is a closed form formula determined accurately by replacing the physical semi-major axis a with the effective semi-major axis $a_{ef}$.

The parameter $a_{ef}$ is used to account for the stored energy in the fringing field of elliptical edge. Therefore$f_{11}^{e,o}$ is a closed form formula determined accurately by replacing the physical semi-major axis a with the effective semi-major axis $a_{ef}$

$$f_{11}^{e,o} = \frac{15}{\pi e a_{ef}}\sqrt{\frac{q_{11}^{e,o}}{\varepsilon_{ef}}}. \tag{2}$$

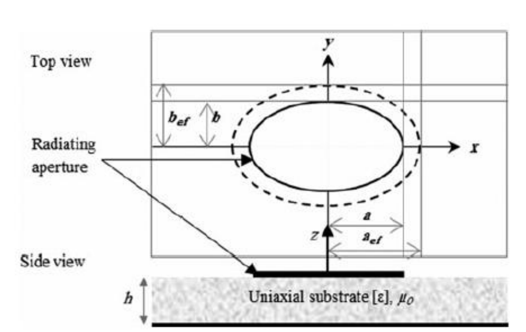

**Fig.1.** Geometrical configuration of EMAs for dual-resonant frequency

Determination of the exact values of Mathieu function qmn eo for the given modes are rather complicated to avoid this complexity, the approximate Mathieu function qmn eo of the dominant even $TM_{11}^{e}$, and odd $TM_{11}^{0}$, can be obtained from

$$\begin{aligned} q_{11}^{e} &= -0.0049e + 3.7888e^2 - 0.7278e^3 + 2.2314e^4, \\ q_{11}^{o} &= -0.0063e + 3.8316e^2 - 1.1351e^3 + 5.2229e^4. \end{aligned} \tag{3}$$

The dual-frequency $f_{11}^{e,o}$ with eccentricities e = $\sqrt(1 - (b/a)^2$corresponding to the aspect ratio [6, 11, 12].

The effective semi-major axis should be considered the suggested approach in [11] is applicable to the EMAs. The

$f_{11}^{e,o}$ of the modified structure for the $TM_{11}^{e}$ mode is calculated

by modifying the equation for a circular microstrip antenna

[12] as given below

$$a_{ef} = \left\{ a^2 + \frac{ha}{0.3525\pi\varepsilon_{ref}} \left[ \ln\left(\frac{a}{2h}\right) + (1.41\varepsilon_{ref} + 1.77) + \frac{h}{a}(0.268\varepsilon_{ref} + 1.65) \right] \right\}^{1/2}. \quad (4)$$

The effective dielectric permittivity 1ef depends on the relative dielectric permittivity 1r and the ratio of the aperture dimensions to substrate thickness of the microstrip antenna [13] as

$$\varepsilon_{ef} = \varepsilon_r - \frac{0.7\varepsilon_r}{2}\left(\frac{h}{a} + \frac{h}{b} + \frac{h^2}{ab}\right). \quad (5)$$

It should be pointed out that the correction to the resonant

frequency (1) in formula (2) involves both the effective permittivity and the effective semi-major axis, what permits to obtain a good agreement between theory and experiment in

the case of the elliptical-disk antenna. If we want to take the substrate uniaxial anisotropy into account, the relative dielectric permittivity Er will be replaced with the tensor Er(ex, ey, ez) where Ex and Ez are the relative dielectric permittivity along x and z axis, respectively.

$$\varepsilon_{eq} = \varepsilon_z, \quad (6)$$

$$h_e = h\sqrt{\frac{\varepsilon_x}{\varepsilon_z}}. \quad (7)$$

**Table 1:** Comparison of calculated and measured resonant frequencies of EMAs with

| $e$ | Measured [17] (GHz) | | calculate [6] | | Present technique (Ghz) | | Absolute error (%) | |
|---|---|---|---|---|---|---|---|---|
| | $f_{11}^{e}$ | $f_{11}^{o}$ | $f_{11}^{e}$ | $f_{11}^{o}$ | $f_{11}^{e}$ | $f_{11}^{o}$ | $f_{11}^{e}$ | $f_{11}^{o}$ |
| 0.273 | 1.410 | 1.385 | 1.417 | 1.389 | 1.415 | 1.388 | 0.354 | 0.216 |
| 0.2178 | 1.400 | 1.378 | 1.401 | 1.385 | 1.399 | 1.383 | 0.071 | 0.362 |
| 0.1836 | 1.380 | 1.370 | 1.394 | 1.383 | 1.392 | 1.381 | 0.869 | 0.802 |
| 0.0894 | 1.370 | 1.370 | 1.382 | 1.379 | 1.380 | 1.378 | 0.729 | 0.583 |

Absolute error % = $|(f_{theo} - f_{meas})|/f_{meas} \times 100$.

h =0.1575 cm, Er= 2.48, a= 4 cm.

**Table 2:** Dependence of dual-resonant frequency on relative permittivities with h =0.3175 cm, Er= 2.48, a= 4 cm, b= 3.84 cm.

| Uniaxial anisotropy type | Relative permittivity | | Anisotropic ratio AR | Resonant frequencies (GHz) | | Fractional change $\Delta f_r/f_r$ (%) | |
|---|---|---|---|---|---|---|---|
| | $\epsilon_x$ | $\epsilon_z$ | $AR = \epsilon_x/\epsilon_z$ | $f_r^e$ | $f_r^o$ | | |
| Isotropic | 2.48 | 2.48 | 1 | 1.328 | 1.354 | 0 | 0 |
| Negative | 4.96 | 2.48 | 2 | 1.281 | 1.307 | 3.54 | 3.47 |
| Negative | 2.48 | 1.24 | 2 | 1.708 | 1.742 | 28.61 | 28.66 |
| Positive | 1.24 | 2.48 | 0.5 | 1.362 | 1.39 | 2.56 | 2.66 |
| Positive | 2.48 | 4.96 | 0.5 | 0.982 | 1.002 | 26.05 | 26.00 |

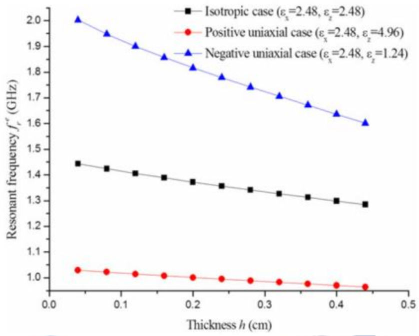

**Fig 2:** Variation of resonant frequency with thickness of EMA even mode

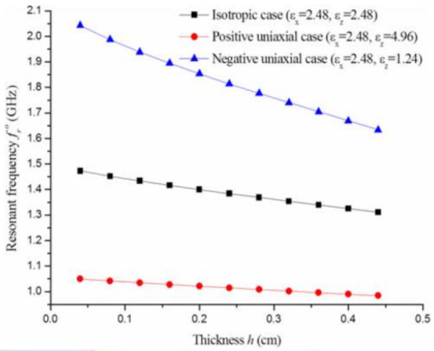

**Fig 3:** Variation of resonant frequency with thickness of EMA odd mode

## 3. RESULTS AND DISCUSSION

In order to examine the computation accuracy of the approach described in the previous section, Table 1 shows the results for the resonant frequencies of elliptical-disk microstrip antenna on isotropic substrate have been compared with previously published results [6, 11].

In Table 1, the results of our model and those calculated and measured by [6, 11] are shown with corresponding percentage error values. It is observed that the results of this

model are better than the results of [11, 6] for isotropic substrate case having smaller percentage error values.

Next, the effect of uniaxial anisotropy on the resonant frequency is analyzed. The anisotropy ratio (AR) is defined as

AR = Ex/Ez.

The resonant frequency of an elliptical microstrip patch antenna with dimensions a = 4 cm, b = 3.84 cm and substrate thickness h = 0.3175 cm, for different pairs of relative permittivities (Ex,Ez) is depicted in Table 2.

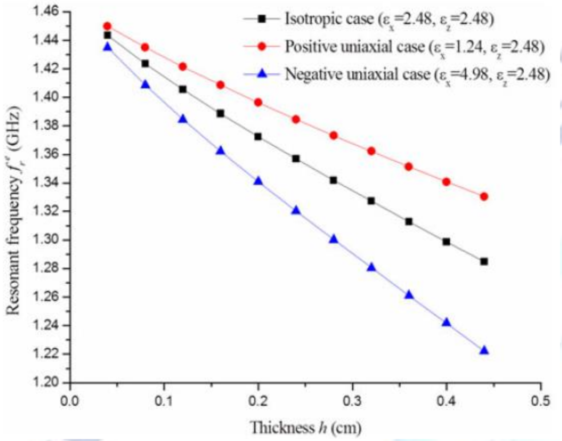

Fig4: Variation of resonant frequency with thickness of EMA even mode

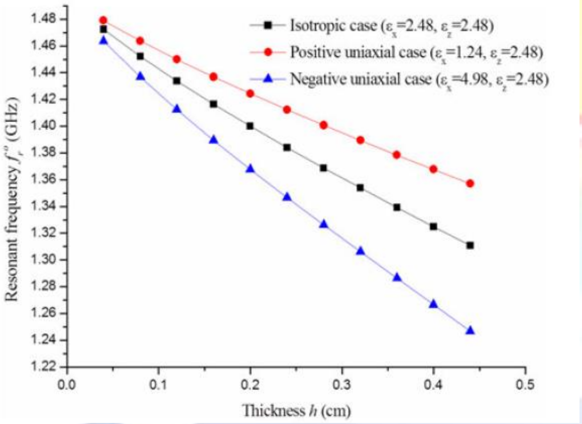

**Fig5:** Variation of resonant frequency with thickness of EMA odd mode

$$\frac{\Delta f_r}{f_r} = \left|1 - \frac{f_{ra}}{f_{ri}}\right|,$$

Where $f_{ri}$ and $f_{ra}$ are, respectively, the resonant frequencies of the antenna for the isotropic and uniaxial anisotropic cases. We observe that, for negative uniaxial anisotropy with AR =2, the resonant frequency $f_{ri}$, can shift to a lower value of $(f_r^e, f_r^o)$ = (1.281, 1.307)GHz or higher frequency of (1.708, 1.742). A similar remark can be made for the positive uniaxial anisotropy case with AR = 0.5; the corresponding values of lower and higher frequencies are, respectively, (0.982, 1.002) and (1.362, 1.390). Consequently, the AR parameter alone is not sufficient to enhance a decision about whether there is an increase or decrease in resonant frequency to be made.

The resonant frequencies of the elliptical patch against the substrate thickness are shown in Figs 1 and 2,3. In Fig. 2, the anisotropy is obtained by changing Ez while keeping Ex constant. The effect of the permittivity along the optical axis persists for low as well as for high substrate thicknesses.

When Ex is changed and Ez remains constant, the influence of the resonant frequency decreases with reductions in substrate thickness as shown in Fig. 3. This influence tends to be neglected for lower substrate thickness. As it can be seen, the dual-resonant $f_r^e, f_r^o$ reduces considerably when the dielectric substrate changes from boron nitride to epsilam-10, and this is in constant to happens when the medium changes from epsilam-10 to sapphire. Also it is observed that the resonant frequency decreases with increases of aspect ratios (b/a).

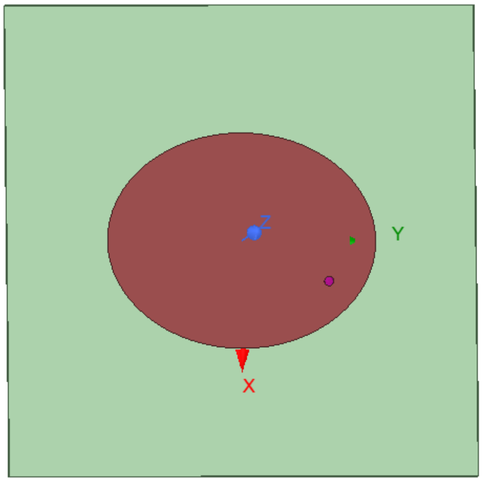

Fig6: Elliptical microstrip antenna using Ansys

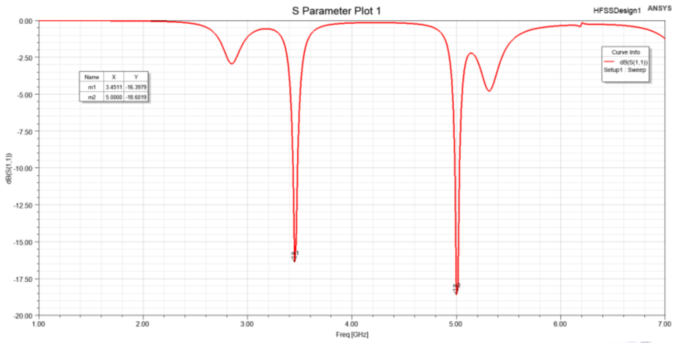

**Fig 7:** Simulation result of dual band Elliptical microstrip antenna using Ansys

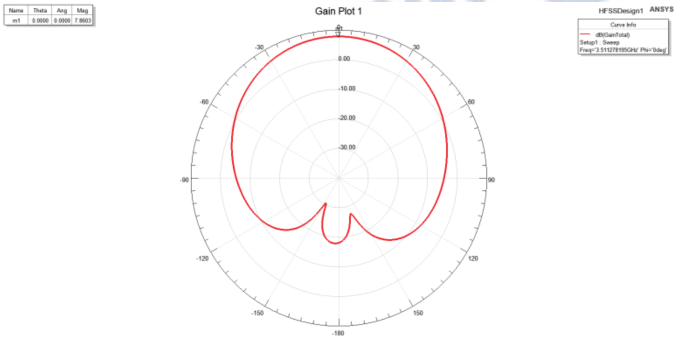

**Fig8:** Radiation pattern at 3.5 GHz

**Parameters:**
**Size of Antenna:** 70mm X 70mm X 1.6mm
**Patch size:** a= 16mm b=12.5mm
**Substrate: Rogers5880** substrate
**Medium:** Air.

Antenna is resonated at dual frequencies 3.5GHz and 5GHz.

## 4. CONCLUSION

This paper presents the expression for predicting the dual resonant frequencies of an elliptical patch microstrip printed on isotropic or anisotropic substrate. This model is suitable for CAD and is directly applicable for the investigation of microstrip antenna in portable wireless equipment. The theoretical results are in very good agreement with experimental results. The obtained results confirm that to predict the dualresonant frequencies variations with anisotropic substrate permittivity, it is necessary to consider both the variation of Ex and Ez, not only the ratio Ex/Ez. Other obtained results show that the dependence of the resonant frequency on Ex decreases with decreasing substrate thickness; for the thin substrates, the permittivity Ez along the optical axis is the most important factor in determining the resonant frequency. The analysis presented here can be extended to study other parameters characterizing the elliptical patch antennas with various structures. Simulated results are discussed.

## Conflict of interest statement

Authors declare that they do not have any conflict of interest.

## REFERENCES

[1] Ansari, J.; Mishra,A.;Yadav, N.P.; Singh, P.; Vishvakarma, B.R.:Analysis of L-shaped slot loaded circular disk patch antenna for satellite and radio telecommunication.Wirel. Pers. Commun., 70 (2) (2013), 927–943.

[2] Xu, F.; Yao, L.; Wang, X.; Qiu, Y.: Effect of conductive yarn crimp in radiation patch on electromagnetic performance of 3D integrated microstrip antenna. Compos. Part B Eng., 43 (2) (2012), 465–470.

[3] Khedrouche, D.; Benghalia, A.: Modeling the superconducting effects on resonance and radiation characteristics of a cylindrical rectangular microstrip antenna covered with a dielectric layer. J. Comput. Electron., 12 (2) (2016), 297–305.

[4] Josan, S.K.; Sohal, J.; Dhaliwal, B.S.: Design of elliptical microstrip patch antenna using genetic algorithms, In IEEE Proc. of the ICCS 2016, 140–143.

[5] Sharma, M.; Yadav, S.; Kumar, A.; Ranga, Y.; Bhatnagar, D.:Compact elliptical microstrip patch antenna with slotted ground for Ku-band applications, In IEEE Applied Electromagnetics Conf. (AEMC), 2018.

[6] Kumprasert, N.: Theoretical study of dual-resonant frequency and circular polarization of elliptical microstrip antennas, In IEEE Antennas and Propagation Society Int. Symp., Salt Lake City, UT, USA, 2000.

[7] Bedra, S.; Bedra, R.; Benkouda, S.; Fortaki, T.: Full-wave analysis of anisotropic circular microstrip antenna with air gap layer. Prog. Electromagn. Res. M, 34 (2014), 143–151.

[8] Djouablia, L.; Messaouden, I.; Benghalia, A.: Uniaxial anisotropic substrate effect on the resonance of an equitriangular microstrip patch antenna. Prog. Electromagn. Res. M, 24 (2012), 45–56.

[9] Benkouda, S.; Fortaki, T.: Study of microstrip patch resonator printed on anisotropic substrate characterized by permittivity and permeability tensors, In PIERS Proc.,Marrakesh, MOROCCO, 20–23 March, 2011.

[10] Motevasselian, A.: Spectral domain analysis of resonant characteristics and radiation patterns of a circular disc and an annula ring microstrip antenna on uniaxial substrate. Prog. Electromagn. Res. M, 21 (2011), 237–251.

[11] Suzuki, Y.; Chiba, T.: Computer analysis method for arbitrarily shaped microstrip antenna with multiterminals. IEEE Trans. Antennas Propag. 32 (6) (1984), 585–590.

[12] Kumprasert, N.; Kiranon, W.: Simple and accurate formula for the resonant frequency of the circular microstrip disk antenna. IEEE Trans. Antennas Propag., 43 (11) (1995), 1331.

[13] Long, S.A.; Shen, L.; Schaubert, D.; Farrar, F.: An experimental study of the circular-polarized elliptical printed-circuit antenna. IEEE Trans. Antennas propag., 29 (1981), 95–99.