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Analytical Comparison of Elliptical Patch and Circular Patch Microstrip Antenna

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ABSTRACT: In this communication a comparative analysis of elliptical patch and circular patch microstrip antenna is presented. We solve wave equation by the Mathieu Special function in combined form as well as separate (Radial and Cylindrical) form. But due to some mathematical complication we had to switch Method of Moment analysis with the help of cavity model of Elliptical elements on thin dielectric substrates support only TM modes. The far field radiation patterns in the Oblate mode are obtained for E plane and H plane.

KEY WORDS: Elliptical Patch Microstrip Array Antenna, Full Wave Analysis, Mathieu Special function, Method of Moment.

I. INTRODUCTION

Elliptical patch geometry is perhaps least analyzed regular shape geometry due to involvement of higher and complex mathematics. The theoretical treatment of the elliptical patch antenna (EPA) has been tried by various numerical techniques. The elliptical shape has several advantages like providing larger degrees of freedom and flexibility in the design, compare to the circular geometry. One of the prominent advantages is circular polarization which can be easily obtained by exciting the elliptical patch rather than rectangular or circular ones by means of the proper selection of feed position of the ellipse. To generate a circular polarization the feed point should be on a radial line positioned relative to the major axis where the positive side axis gives left-hand circularly polarized (LHCP) while the negative axis gives right-hand circularly polarized (RHCP). Furthermore, the elliptic antenna offers greater flexibility in the design by utilizing the eccentricity and the focal length to fine tune the antenna to the desired performance [1-4].

Although there have been several methods used to analyze the regular patch geometries like circular, rectangular, triangular, etc. using spectral domain analysis [12], transmission line method, cavity model, resonant equivalent circuits and the method of moments [13-14] but they had the shortcomings of degrading accuracy as the thickness of the substrate increases in case of elliptical geometry [7-11]. These numerical techniques take a significant amount of computational time, even when considering just one or two modes, thus making interactive design a difficult task. The more direct approach, Green's function approach, which is generally used for circular and rectangular patches [15], had not been applied to the EPA because a computationally efficient Green's function was not available. Though approximate solutions were devised by some researchers explained in [16] and [17], these approximations are limited to small eccentricities and have dealt with the TM_{11} mode only. It is, however, complicated to analyze the elliptical-patch geometry because of its unique elliptical characteristics.

II. THEORY

The geometry of elliptical patch microstrip antenna is shown in figure 1. The elliptical patch of major axis '2a' and minor axis '2b' printed on RT-duroid substrate of thickness 'h'.

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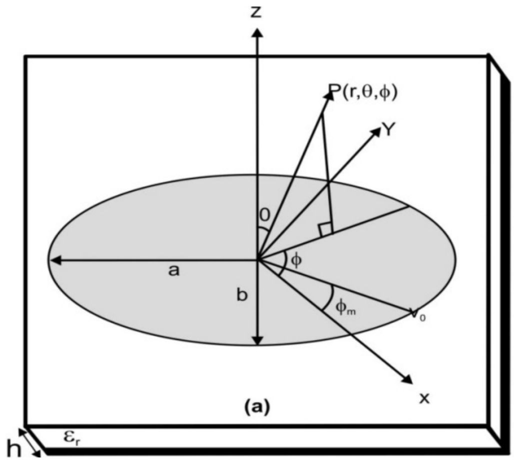

Figure 1: *Geometry of microstrip rectangular patch antenna*

The properties of the elliptic patch as a microstrip antenna have been investigated through extensive experimentation, though these properties have not been verified by any one general theory. In the present work we have tried two mathematical analysis **(1)** Full Wave Analysis and **(2)** Method of Moment with Cavity Model, to study the elliptical patch antenna (EPA) [16-20].

E-Plane (φ = 90°)

For Oblate Ellipse:

$$E_r = E_\varphi = 0 \quad (1)$$

$$E_\theta = j\frac{k\,a^2 E_o e^{-jkr}}{r}\left\{\frac{J_1(ka\sin\theta)}{ka\sin\theta}\right\} \quad (2)$$

For Prolate Ellipse:

$$E_r = E_\varphi = 0 \quad (3)$$

$$E_\theta^{'} = j\frac{k\,b^2 E_o e^{-jkr}}{r}\left\{\frac{J_1(kb\sin\theta)}{kb\sin\theta}\right\} \quad (4)$$

H-Plane (φ = 0°)

For Oblate Ellipse:

$$E_r = E_\theta = 0 \quad (5)$$

$$E_\eta = j\frac{k\,a^2 E_o e^{-jkr}}{r}\left\{\cos\theta\left[\frac{J_1(ka\sin\theta)}{ka\sin\theta}\right]\right\} \quad (6)$$

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For Prolate Ellipse:

$$E_r = E_\theta = 0 \tag{7}$$

$$E_\eta^{'} = j\frac{k\,b^2 E_o e^{-jkr}}{r}\left\{\cos\theta\left[\frac{J_1(kb\sin\theta)}{kb\sin\theta}\right]\right\} \tag{8}$$

III. CALCULATION & RESULTS

The radiation patterns and radiation parameters have been plotted and calculated respectively. An ellipse patch of oblate radius 0.61 cm & prolate 0.61 cm, is printed with elements separation $d_x = d_y = 3$ cm on RT-duroid substrate of $\varepsilon_r = 2.33$ and height h = 0.165 cm.

Radiation Patterns: The far field radiation patterns in the Oblate mode are obtained for E plane ($\varphi = \pi/2$) and H plane ($\varphi = 0^0$).

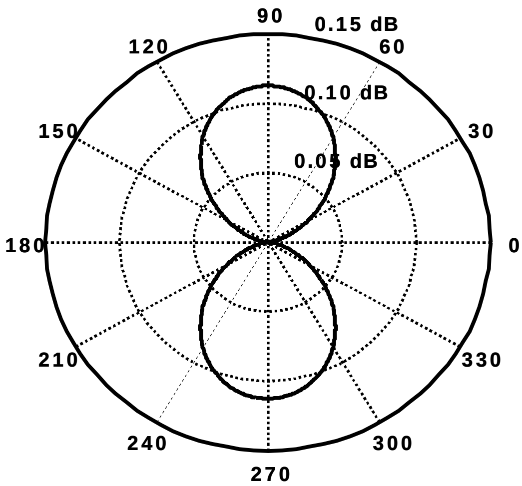

Figure 3: *Radiation pattern of elliptical patch antenna in E-plane ($\varphi = \pi/2$)*

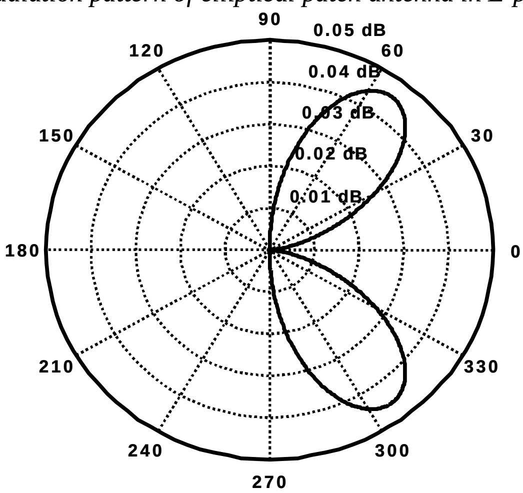

Figure 4: *Radiation pattern of elliptical patch antenna in H-plane ($\varphi = 0^0$)*

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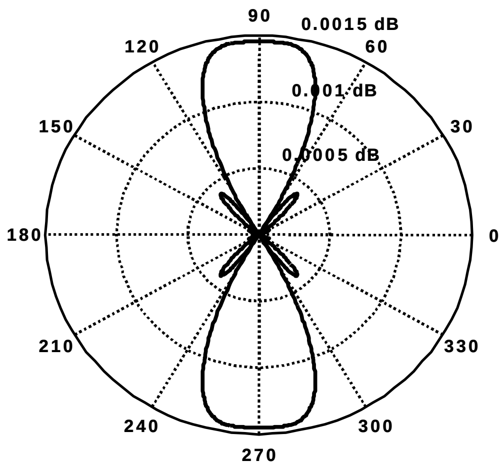

Figure 5: *Variation of R(θ,φ) for 4×4 elliptical microstrip array configuration*

The total field pattern R(θ,φ) is generally obtained by the relation: $R(\theta,\varphi) = |E_\theta|^2 + |E_\varphi|^2$. The planar array pattern is computed for source frequency f_r = 10 GHz with progressive phase excitation $b_x = b_y = 0$. The patterns of E plane, H plane and planar array are shown in fig. 3, 4 & 5 respectively.

Radiation Parameters: All important parameters like bandwidth, directive gain, total impedance and quality factor of circular and elliptical microstrip patch antenna printed on RT-duroid has been calculated and tabulated in table 1.

Table 1: *Comparison of characteristics of circular and elliptical microstrip patch antenna printed on RT-duroid*

Radiation Parameters	**Values**	
	Circular Patch	**Elliptical Patch**
Radius /Oblate (a)	0.51 cm	0.61 cm
Prolate (b)	--	0.51 cm
Bandwidth (BW)	2.99 %	2.84 %
Directive Gain (D_g)	6.59 dB	8.37 dB
Q. Factor (Q_F)	13.62	14.35
Total Imped. (Z_{in})	124ohms	136ohms

IV. CONCLUSION

In the present work the full wave analysis has been applied to investigate the elliptical patch antenna but due to the mathematical complexities of Mathieu's and modified Mathieu's function, the analysis stopped after some even important results. The involvement of these functions makes mathematics of elliptical patch geometries extremely difficult. After this the Method of Moment has been applied with cavity model of elliptical patch antenna.

Theoretical results of elliptical patch antenna have been developed by Method of Moment analysis with the help of cavity model. Radiation field patterns for E-plane, H-plane and array configuration have been plotted for oblate form. There are very similarities between the field expressions, radiation patterns and radiation parameters of circular

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and elliptical geometries. The calculated radiation parameters of elliptical microstrip antennas have been tabulated and compared with the results calculated for circular microstrip antenna with same configuration and frequency range.

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