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REGULAR ARTICLE

Analysis of an Elliptical Microstrip Slotted EPA for Wi-Max Applications

Loya Surendra[1], Ambati Navya[2], Vasudeva Bevara[3,*], Mahesh Valathuru[4]

[1] *Department of ECE, Mallareddy (MR) – Deemed to be University, Medchal Telangana, India*
[2] *Department of ECE, KLEF, Vaddeswaram, Guntur, Andhra Pradesh, India*
[3] *Department of Electronics and Communication Engineering, GMR Institute of Technology (GMRIT) – Deemed to be University, Rajam, 532127 Andhra Pradesh, India*
[4] *Department of ECE, Sri Venkateswara College of Engineering, Karakambadi Road, Tirupati, 517507 Andhra Pradesh, India*

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As wireless communication progresses towards wireless communication applications, antennas operating at Sub-6 GHz frequencies must be employed. This is necessary to meet the increasing demand for low latency connectivity and rapid data transmission. However, the inability of traditional antenna designs to provide the necessary bandwidth, gain, and efficiency at these high frequencies limits their suitability for use with 5G technology. Among the various shaped MPAs, EMPA has become a unique and important category due to its compact size, wide frequency range with a single feed. The design of EMPA is more flexible than that of antennas with circular or rectangular geometries, making it a promising re-search topic. EMPA occupies an area of $25.2 \times 32 \times 1.6$ mm^3 and it is designed by utilizing a FEM analysis tool called An-soft HFSS. FR4 substrate has been utilized in the design of EMPA which has the dielectric properties like ε_r of 4.4 and tan δ of 0.02. EMPA resonates at 3.3 GHz and it offers reflection coefficient of – 18.6 dB. Bandwidth of 0.7 GHz (2.9 GHz-3.6 GHz) and VSWR of 1.26 has been observed for EMPA. Omni directional and bidirectional radiation pattern has been observed at 3.3 GHz for different values of θ and Φ. These results make the EMPA suitable for Wi-Max applications.

Keywords: Wi-Max applications, EMPA, Compact Size and Elliptical.

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1. INTRODUCTION

Dual resonant frequencies and circular polarization are necessary for numerous real-time applications, including radar, systems for navigation, communication, and telephony. Circular polarization for wireless applications is accomplished by changing the rectangular micro-strip patch antenna's form or by using several feeds. An EMPA is designed to obtain circular polarization of the antenna for wireless communication applications [1]. LHCP waves are produced by positive signs, whereas RHCP waves are produced by negative signs. Radiation properties of the antenna are defined in terms of LHCP, RHCP and Mathieu Functions can be produced in a restricted frequency band for EMPA with modest eccentricity values. An elliptical patch antenna is designed to obtain multi-band as well as circular polarization, a theoretical investigation was carried out [2]. The impedance bandwidth in terms of the eccentricity, radiator's size and thickness was calculated using a resonant circuit design that was designed to simulate EMPA [3]. It was described how to determine the operating frequency of the prominent modes of EPAs in a simpler and more precise manner [4]. When the eccentricity was high, the bandwidth of the even mode was found to be poor. Additionally, compared to the odd mode even mode exhibited a wider radiation pattern with less cross-polarization. A simple approach was presented to find out the resonant frequency of the MPA for wireless communication applications [5]. Additionally, it is claimed that an elliptical construction operates in a larger frequency range than a circular one. An extra degree of freedom was the eccentricity value [6]. An EPA was designed and analysed by employing elliptical resonators by employing even and odd mode analysis for wireless communication applications [7]. An elliptical-disk MPA is designed by utilizing isotropic substrate materials [8].

An EPA is designed by employing surface wave dispersion for anisotropic metasurfaces for wireless communication applications [9]. An experimental study was carried out for circular-polarized elliptical printed-circuit antenna with the help of even and odd mode analysis [10]. Five distinct ellipses with two varying printed circuit board thicknesses have eccentricities ranging from 1.00 to 0.96. The antenna with an eccentricity value of 0.976 generated the best circular polarization. The broad applications of EMPAs necessitate quicker design technique development, which calls for more efforts from the scientific community. Prerequisites for such an excursion include a complete understanding of contemporary methods and approaches employed by researchers. The goal of this

* Correspondence e-mail: vasudeva.b@gmrit.edu.in

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work is to critically design and analyse EMPA having an elliptical slot at the center and how they affect antenna performance. The research is structured as follows: section 2 provides the crucial formulas for calculating the resonant frequency, a crucial feature of an EMPA, and section 3 provides a detailed description of the design technique classifications and how they affect the antenna's performance metrics. Section 4 concludes the research article.

2. DESIGN & ANALYSIS OF EMPA

By adding slots of various shapes to the patch, EMPA performance can be enhanced. Numerous studies on RPA and CPAs have been documented in the literature. There are relatively few studies that use slots on an elliptical patch to improve its performance. A 1.6 mm thick elliptical patch including an elliptical slot and a microstrip transmission line having an impedance of 50 Ω was printed on the uppermost layer of FR4 substrate. The bottom side of the substrate is a partial ground plane. Fig. 1 represents the top surface and bottom surface of the EMPA. Partial ground plane has been utilized to obtain the better antenna performance. EMPA is designed by attaching a microstrip rectangle having dimensions 6.1 mm × 18 mm to 6 mm radian ellipse. After that a 4 mm radian ellipse is subtracted and then a 2 mm radian circle is united to the existing design. Then the same design is replicated to the right side of the feed line. EMPA is designed and analyzed by utilizing a finite element method tool called An-soft HFSS. EMPA occupies an area of 25.2 × 32 × 1.6 mm^3. EMPA is designed by utilising FR4 material having 4.4 ε_r, a tan δ of 0.02 and a thickness of 1.6 mm. EMPA is designed by utilising the following mathematical formulae.

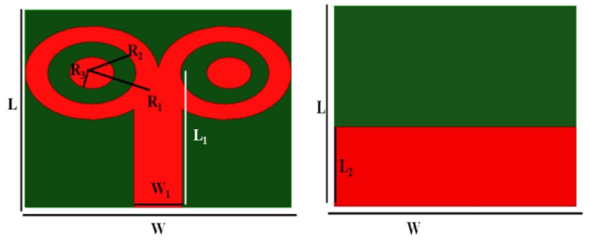
$$L = \frac{c}{2F_r\sqrt{\varepsilon_{reff}}} - 2\Delta l \tag{1}$$

$$a = \frac{F}{\sqrt{1+\frac{2h}{\Pi\varepsilon_r}[\ln\left(\frac{\Pi f_r}{2h}\right)+1.7726]}} \tag{2}$$

$$F = \frac{8.791*10^9}{f_r\sqrt{\varepsilon_r}} \tag{3}$$

$$\varepsilon_{\text{reff}} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+\left[\frac{12h}{w}\right]\right]^{-1/2} \tag{4}$$

In the elliptical patch, 'a' stands for the radius, which is found using Eq. (2), and 'L' for the length, which is found using (1). In this case, the variable 'h' stands for the material's thickness. Eq. (2) is used to generate F. The center frequency of the substrate is represented by f_r.



a b

Fig. 1 – EMPA (a) Top surface (b) Bottom surface

Table 1 – Dimensions of the EPA

Parameter	Values (mm)
L	25.2
W	32
L_1	18
W_1	6.1
L_2	10
R_1	6
R_2	4
R_3	2

3. RESULTS AND DISCUSSION

S_{11} and VSWR of EMPA is shown in Fig. 2. EMPA resonates at 3.3 GHz (2.9 GHz-3.6 GHz) and offers a reflection coefficient of – 18.6 dB. Generally, VSWR of any microwave component has to be in the range of 1 to 2. VSWR of the EMPA is shown in Fig. 2 and VSWR of 1.2 has been observed at 3.3 GHz. This represents that there aren't many reflected signals, guaranteeing effective signal transmission and reception. The overall gain for EMPA is represented in three dimensions in Fig. 3. Different colours indicate different gain levels, while the colour bar on the left shows the antenna's total gain in dB. A maximum gain of 5.7 dB has been observed at 3.3 GHz. Radiation pattern of the EMPA at 3.3 GHz is shown in Fig. 4. Good co-pol and cross-pol differences in the broadside direction, i.e., more than 20 dB at all two frequency bands, are present in both major planes (E&H). Fig. 4 shows that at the resonant frequency, the radiation in the E- and H-planes is omnidirectional and bidirectional. EMPA has good radiation properties. Fig. 5 displays the EMPAs current distribution. The colour red represents the largest field distribution. It has been observed that the maximum value is 10 Am^{-1}. Maximum amount of distribution is represented by using red colour and is observed across the corners and center of the patch. These results make the EMPA suitable for Wi-Max applications.

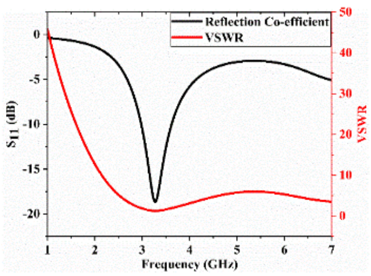


Fig. 2 – VSWR and Reflection Co-efficient of the EMPA

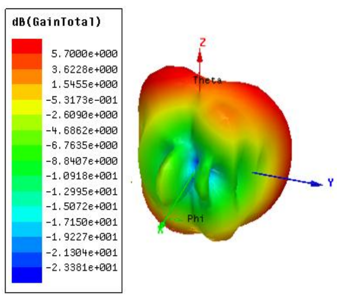


Fig. 3 – Obtained Gain of the proposed EMPA

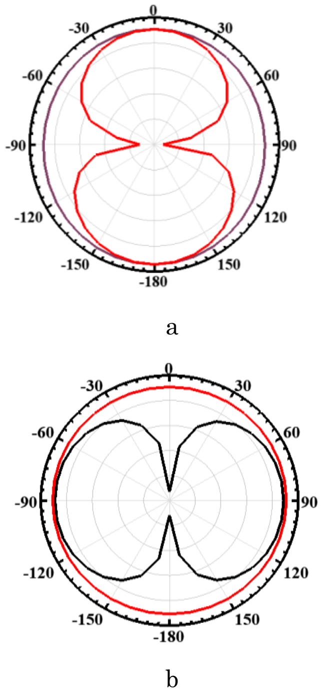


Fig. 4 – Radiation pattern for EPA at 3.3 GHz (a) *E*-plane (b) *H*-plane

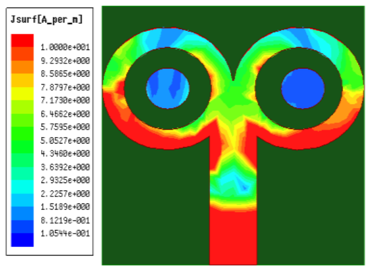


Fig. 5 – Proposed EMPA's Surface current distribution

As shown in Table 2, EMPAs performance is compared to the antennas reported in references [11-15]. When compared with the antennas in the existing literature, even though it occupies more space offers high gain. The PCB method is an effective way to design it and it is composed of a single layer.

Table 2 – Comparison table for circular-slotted ESA

Ref	Overall Size (λ_0)	Resonant Frequency	Number of Layers	Gain (dB)
[11]	0.2010 × 0.0610	0.58	Single layer	– 2.4
[12]	0.062 × 0.118	2.36	Single layer	– 1.9
[13]	0.08 × 0.0479	2.4	Single layer	– 1.9
[14]	0.05 × 0.05	0.5	Six layers	≈ – 2.1
[15]	0.1 × 0.06	2.42	Single layer	– 8.72
This paper	0.27 × 0.35	3.3	Single layer	5.7

4. CONCLUSION

EMPA occupies an area of 25.2 × 32 × 1.6 mm^3 and it is designed by utilising a FEM analysis tool called An-soft HFSS. FR4 substrate has been utilised in the design of EMPA which has the dielectric properties like ε_r of 4.4 and tan δ of 0.02. EMPA resonates at 3.3 GHz and it offers reflection coefficient of – 18.6 dB. Bandwidth of 0.7 GHz (2.9 GHz - 3.6 GHz) and VSWR of 1.26 has been observed for EMPA. Omni directional and bidirectional radiation pattern has been observed at 3.3 GHz for different values of θ and Φ. 3 dBi gain of 5.7 dB has been observed at 3.3 GHz. These results make the EMPA suitable for Wi-Max applications.

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Аналіз еліптичного мікросмужкового щілинного EPA для застосувань Wi-Max

Loya Surendra[1], Ambati Navya[2], Vasudeva Bevara[3], Mahesh Valathuru[4]

[1] *Department of ECE, Mallareddy (MR) – Deemed to be University, Medchal Telangana, India*
[2] *Department of ECE, KLEF, Vaddeswaram, Guntur, Andhra Pradesh, India*
[3] *Department of Electronics and Communication Engineering, GMR Institute of Technology (GMRIT) – Deemed to be University, Rajam, 532127 Andhra Pradesh, India*
[4] *Department of ECE, Sri Venkateswara College of Engineering, Karakambadi Road, Tirupati, 517507 Andhra Pradesh, India*

З розвитком бездротового зв'язку переходять до використання антен, що працюють на частотах нижче 6 ГГц. Це необхідно для задоволення зростаючого попиту на з'єднання з низькою затримкою та швидку передачу даних. Однак нездатність традиційних конструкцій антен забезпечити необхідну пропускну здатність, коефіцієнт посилення та ефективність на цих високих частотах обмежує їх придатність для використання з технологією 5G. Серед MPA різної форми, EMPA став унікальною та важливою категорією завдяки своїм компактним розмірам, широкому діапазону частот з одним живленням. Конструкція EMPA є більш гнучкою, ніж у антен з круглою або прямокутною геометрією, що робить його перспективною темою дослідження. EMPA займає площу 25,2 × 32 × 1,6 мм^3 та розроблений з використанням інструменту аналізу скінченних елементів під назвою An-soft HFSS. У конструкції EM-PA було використано підкладку FR4, яка має діелектричні властивості, такі як ε_r 4,4 та tan δ 0,02. EMPA резонує на частоті 3,3 ГГц і пропонує коефіцієнт відбиття – 18,6 дБ. Для EMPA спостерігалася смуга пропускання 0,7 ГГц (2,9 ГГц-3,6 ГГц) та КСХН 1,26. На частоті 3,3 ГГц спостерігалася всеспрямована та двоспрямована діаграма випромінювання для різних значень θ та Φ. Ці результати роблять EMPA придатним для застосувань Wi-Max.

Ключові слова: Wi-Max застосування, EMPA, Компактний розмір та еліптичний тренажер.