# 行政院國家科學委員會專題研究計畫　成果報告

## 雙頻圓極化介質共振天線模組之設計及研發

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# 摘要

關鍵字：介質共振天線， 雙頻天線，圓形極化

本計畫已成功地研發一雙頻圓極化介質共振天線(DRA)。吾人採用橢圓型介質共振天線來設計一個雙頻的天線，並使用同軸傳輸線來作饋入設計。本文中所設計的雙頻共振天線為同模雙頻天線，即是頻率不同但輻射場形一致的雙頻天線。在本論文中天線輻射模態選擇$HEM_{11\delta}$模態來作為兩個不同頻段的首位模態。$HEM_{11\delta}$模態其遠場輻射場形在天線正上方為一個對稱性的圓弧，此可等效成一個magnetic dipole在橢圓軸心輻射的結果。本報告包括設計、模擬、實作、及量測之結果。

# ABSTRACT

Keywords：Dielectric Resonator Antennas, Dual Band Antennas, Circularly Polarized Antennas

The project has successfully completed the design and implementation of a dual band circularly polarized dielectric resonator antenna (DRA). An elliptical dielectric resonator is employed to realize the dual band design with co-axial probe feed. The dual ports is arranged orthogonally and generate the same $HEM_{11\delta}$mode that leads to the same radiation pattern with peak gain on the broad sight. Such a mode can be considered as the equivalent magnetic dipole above the ground plane perpendicular to the port axis. This report covers the design, simulation, prototype, and measurement results.

一.前言

近幾年來由於個人通訊網路(personal communication network, PCN) 與個人通訊服務(personal communication services, PCS) 的蓬勃發展，使得人與人之間的訊息交流愈來愈便利與即時，因此不論是在日常生活中或是商業市場上甚至於學校課程裡，無線通訊(wireless communication)都愈來愈受到眾人矚目。

無線區域網路(wireless local area network, WLAN) 即是結合了行動通訊(mobile communication)和區域網路(local area network, LAN)兩種潮流而生的規格，它的基本想法便是希望藉由無線電波的傳遞，來達到資料傳輸與資源共享的目的[1-2]，由於不需鋪設電纜，因此可以節省成本且也免去鑿壁而破壞環境美觀。綜合以上可知，無線區域網路具有良好的機動性與方便性，尤其近幾年來筆記型電腦(laptop)與掌上型電腦(例如 PDA)普及率增加，使用者對上網的需求也大幅提高，其發展潛力與市場之大可見一斑。

二.研究目的

無線傳輸中，天線是不可或缺的元件之一，在今日已有許多適用於 WLAN 的天線，不論是凸出型單極天線(monopole antenna) ，塊狀天線(patch antenna) ，或是印刷雙極天線(printed dipole antenna)，在無線區域網路基地台運用上，皆有不錯的表現。不過這些天線普遍上來說，體積與面積都稍大一些，在美觀與基地台的整合性上比較缺少優勢。介質共振天線(dielectric resonator antenna, DRA)，有著許多吸引人的特性，例如小體積，高輻射效率，多種簡易饋入方式與及簡單幾何等等。因此本文目的為在 DRA 同模雙頻天線設計上作一個前端學術探討。

三. 文獻探討

介質共振器可往自由空間輻射的想法首先是由 Richtmyer[3]在 1939 年所做的論文中實現的，而在 1967 年 Gastine et al 則提出了球體形狀的介質共振天線的輻射 Q-factor 的研究[4]，此外 Sager and Tisi 則在 1975 年首先提出使用介質共振器作為一個小型天線的理念[5]。之後 Van Bladel 便針對任意形狀的介質共振器提出了一個嚴謹的漸進理論[6-7]，且運用數值方法計算出圓環形柱介質共振器(cylindrical ring dielectric resonators)的共振頻率、輻射場形與 Q-factors [8-10]。在介質共振的研究歷史中，最早發展出有系統性的理論與實驗去研究介質共振天線結構的學者是 Long[11]，之後便有許多學者一直在研究各種形狀的介質共振天線，例如圓柱型，矩型[12]，球面體型[13]與圓環柱型[14]等等。

四.研究方法

由於欲設計的天線結構是三維的結構，故本研究採用全三維的電磁分析軟體Ansoft HFSS [15]來作模擬與設計。欲設計一個輻射場形皆為首位模態$HEM_{11\delta}$的雙頻天線，吾人設計一個橢圓介質共振天線，且採用兩個同軸傳輸線饋入天線的方式來確保其兩個頻率共振點輻射場形皆為$HEM_{11\delta}$ 的輻射場形。圖 1 與圖 2 分別為所設計的橢圓介質共振天線幾何圖形及實作相片，其中橢圓長邊R在y軸方向其大小為 15mm，短邊r在x軸方向其大小為 4.6mm，橢圓高度H為 9mm，介電常數選用 37，接地金屬板尺寸為 50mm X 50mm。長邊饋入為port 1，短邊饋入為port 2。

電腦模擬與實驗量測的 return loss 頻率響應展示在圖 3。由圖 3(a)中可知，實際量測的低頻共振點頻率為 2.43GHz，此比模擬所得共振頻率(2.4GHz)略偏高了 1.6%，而實際量測的頻寬約為 3.4%；由圖 3(b)可知，實際量測的高頻共振點頻率為 3.26GHz，此比模擬所得共振頻率(3.32GHz)略偏低了 1.2%，而實際量測的頻寬約為 4%。

圖 4 與圖 5 為實際量測與模擬所得輻射場形。 圖 4(a)為低頻輻射的 H-plane，其模擬的最大指向性(Directivity)為 5.42dBi 而實際量測最大增益(Gain)為 4.63dBi；圖 4(b)為低頻輻射的 E-plane，模擬的最大指向性(Directivity)為 5.42dBi 而實際量測最大增益(Gain)為 3.927dBi，低頻的輻射場形與模擬的值有不錯的一致性，輻射方向皆為天線的正上方(broad side)。圖 5(a) 為高頻輻射的 E-plane，其模擬的最大指向性(Directivity)6.45dBi 而實際量測最大增益(Gain)為 5.069dBi；圖 5(b)為高頻輻射的H-plane，模擬的最大指向性(Directivity)為 6.45dBi 而實際量測最大增益(Gain)為4.529dBi，高頻的輻射場形與模擬的值有不錯的一致性，輻射方式皆為往天線的正上方輻射(broad side)。

由實驗與模擬比較可知，同軸傳輸線饋入的橢圓介質共振天線有不錯的一致性，也很符合我們預期的目標，輻射增益有 4～5dBi 左右，可知其輻射效率不低，而頻寬也約為 4%左右。

五.結果與討論

吾人採用橢圓型介質共振天線來設計一個雙頻的天線，並使用同軸傳輸線來作饋入設計。本文中所設計的雙頻共振天線為同模雙頻天線，即是頻率不同但輻射場形一致的雙頻天線。在本論文中天線輻射模態選擇$HEM_{11\delta}$模態來作為兩個不同頻段的首位模態。$HEM_{11\delta}$模態其遠場輻射場形在天線正上方為一個對稱性的圓弧(broad-side)，此可等效成一個magnetic dipole在橢圓軸心輻射的結果。

使用橢圓介質共振天線作雙頻天線，可知低頻產生在橢圓長軸的共振(y 軸饋入)，其

在 x 軸會得到一個等效的 magnetic dipole 來輻射，因此 xz 平面為 H-plane，yz 平面為 E-plane；而高頻產生在橢圓短軸共振(x 軸饋入)，其在 y 軸會得到一個等效的 magnetic dipole 來輻射，因此 xz 平面為 E-plane，yz 平面為 H-plane。此時兩頻段輻射場形之極化互相垂直，此乃是因為饋入天線時，低頻與高頻的共振方向即有相差 90 度的方位角。

本研究成果所發表之論文著作，包括一篇會議論文（Conference Paper）[16]及一本學生畢業論文 [17]。

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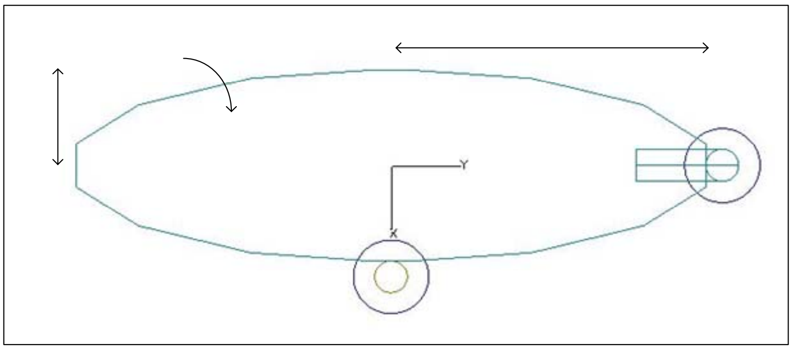
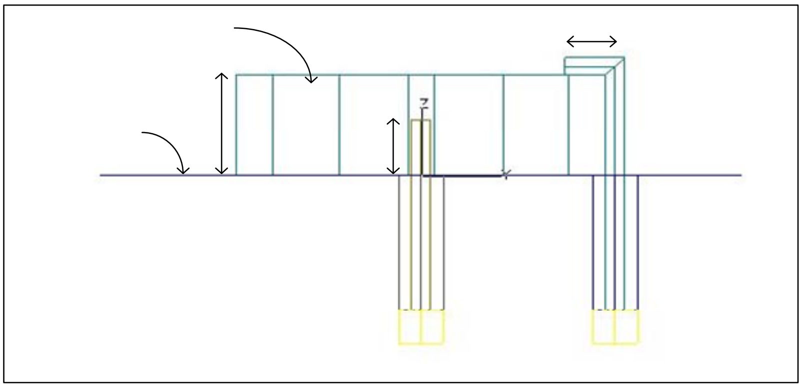
# 附圖

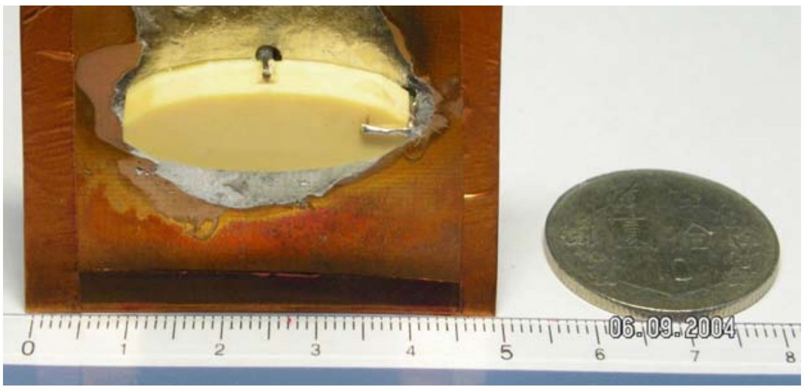


(a)



(b)

圖 1. 橢圓介質共振天線幾何圖形 (a)俯視(b)側視




r=4.6

圖 2. 橢圓介質共振天線實作與十元硬幣比較圖

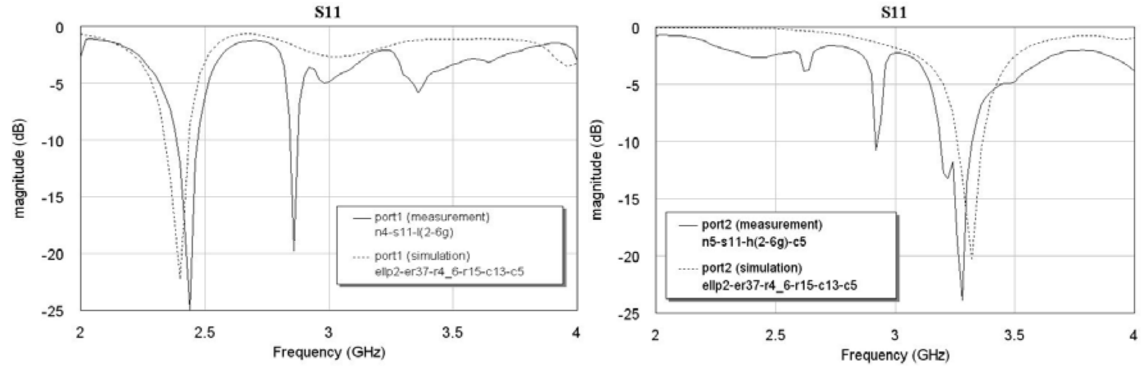
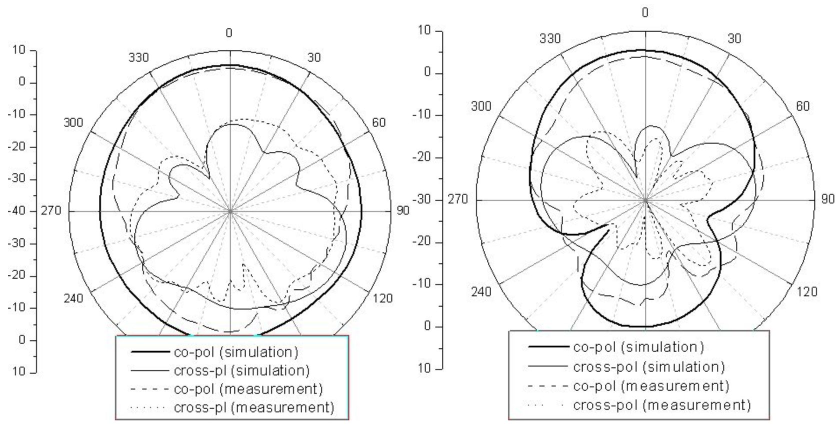
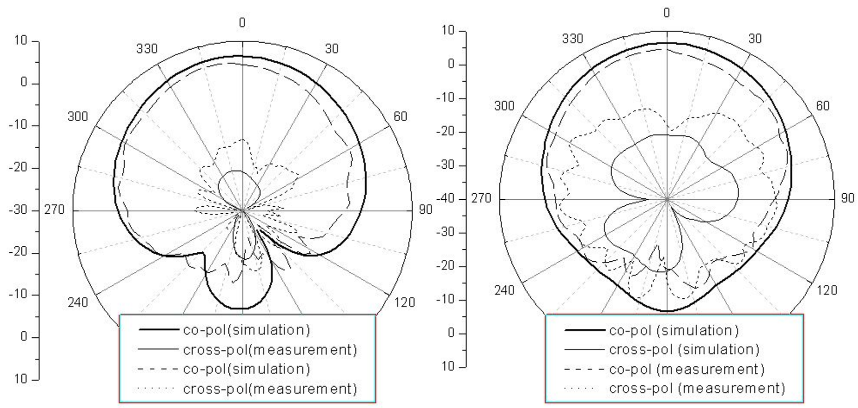



圖 3. 橢圓介質共振天線反射損耗之頻率響應 (左)Port-1 低頻(右)Port-2 高頻




(a) H-plane (xz plane)　　　(b) E-plane (yz plane)

圖 4. 橢圓介質共振天線之低頻(f=2430MHz)輻射場形




(a) E-plane (xz plane)　　　(b) H-plane (yz plane)

圖 5. 橢圓介質共振天線之高頻(f=3260MHz)輻射場形

# A Dual Band Elliptical DRA

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**Abstract**: This paper presents a dual band frequency antenna by using an elliptical dielectric resonator antenna. We describe an elliptical dielectric resonator antenna on a ground plane. Dual bands are obtained by utilizing two coaxial feeds on two sides of the elliptical DRA. A simulation result of the return loss and the radiation characteristic of the elliptical DRA is included.

## 1. Introduction

In recent years dielectric resonator antennas (DRAs) have been widely studied by many researchers [1-2]. The features and flexibility of DRAs antennas are their high radiation efficiency, large bandwidth, simple coupling, low cost, small size and so on. In this paper, we present a dual band antenna by using a single elliptical DRA. The elliptical DRA is fed by two coaxial cables, and the dual frequency is designed. The size, return loss and radiation patterns of the elliptical DRA are simulated shown in the paper. All simulation results in this paper are based on the full wave analysis of finite element methods through the commercial software HFSS [3].

## 2. Antenna Structures

In order to generate the dominant modes($HEM_{11\delta}$) of cylindrical DRAs [4], we choose two ports to excite different frequency, and by using two ports to receive different frequency signal, we can omit the diplexer in the circuit. Figure 1 and Figure 2 show the geometry of the elliptical DRA on the ground plane. The relative permittivity $\varepsilon_r$ of the elliptical DR is 37 and the ground plane is 50.8mm x 50.8mm. The long radius (R) of the elliptical antenna is 15mm for exciting the lower frequency while the short radius (r) of the elliptical DRA is 4.6mm for exciting the upper frequency. The height (H) of the DR is 9mm and the DR is fed by two 50Ω coaxial cables with the same phase. Probe of Port 1 is bent at the top corner of DRA and extended 4mm inward to match the 50Ω impedance. While the probe of of Port 2 is 5mm, less than the elliptical DRA height, for impedance matching.

## 3. Results

The return loss of the elliptical DRA fed by two coaxial cables is show in Figure 3. The long axis is resonant at 2.44GHz, and the short axis is resonant at 3.36GHz. The pattern of an elliptical DRA fed by Port 1 to excite lower resonant frequency is equivalent to that of a magnetic dipole lying along x axis and its H-plane (xz-plane) and E-plane (yz-plane) are respectively shown in Figure 4 and Figure 5. The max directivity of the lower resonant frequency is 4.9 dBi. In this case, the mode of the lower frequency is $HEM_{11\delta}$.On the other hand, the pattern of an elliptical DRA fed by Port 2 to excite upper resonant frequency is equivalent to that of a magnetic dipole lying along y axis and its E-plane(xz-plane) and H-plane(yz-plane) are respectively shown in Figure 6 and Figure 7. The max directivity of the upper resonant frequency is 6.1 dBi. In this case, the mode of the upper frequency is also $HEM_{11\delta}$.

## 4. Conclusions

This paper presents a simple structure with dual bands and the performance of the elliptical DRA. The elliptical DRA size is compact and easy to manufacture. Moreover, impedance match is also solved by extending or shortening the probe of each port. According to the applications, users can choose suitable elliptical radius to generate desired frequency and tune the length of each probe to match well.

## 5. Acknowledgment

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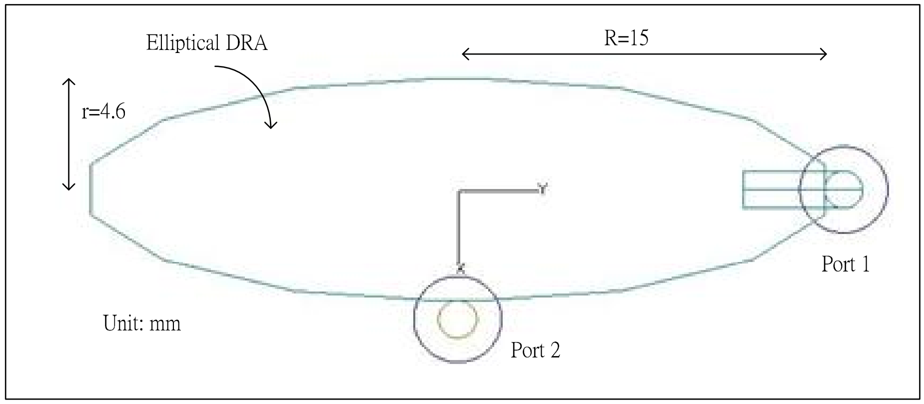


Fig. 1: Top view of the elliptical DRA

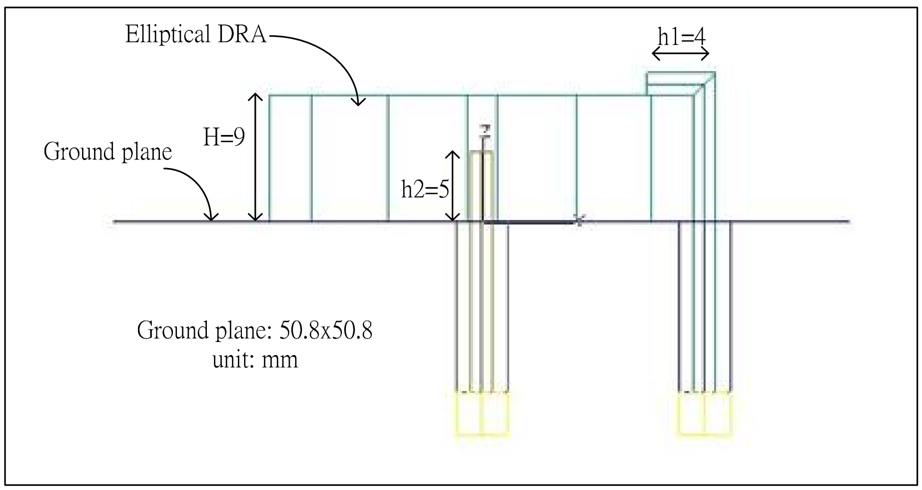


Fig. 2: Side view of the elliptical DRA

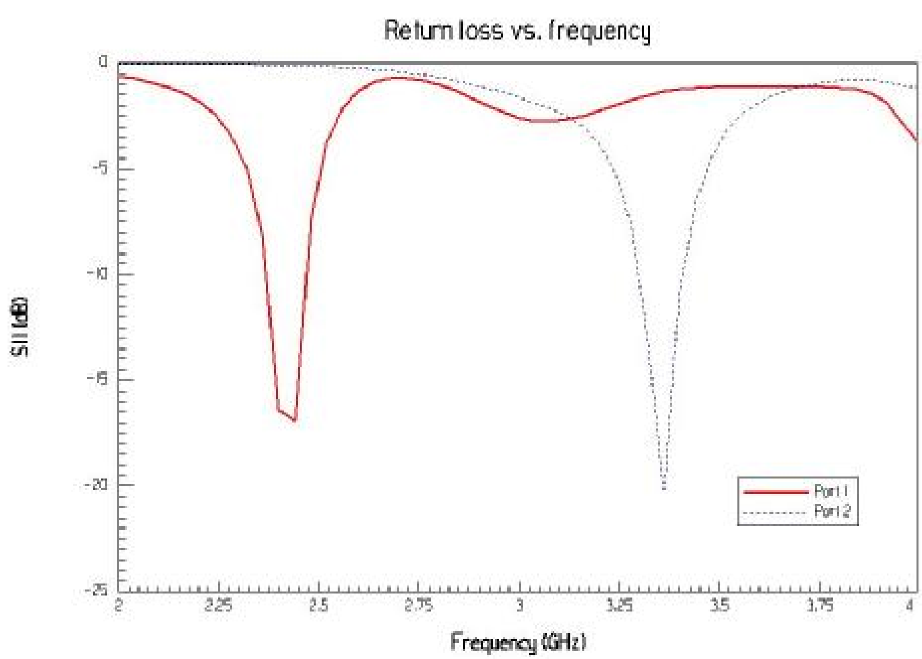


Fig. 3: Return loss vs. frequency of Port 1 and Port 2

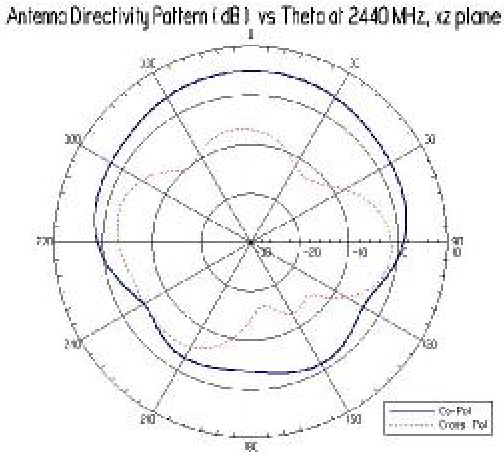


Fig. 4: H-plane pattern of the elliptical DRA at 2.44GHz

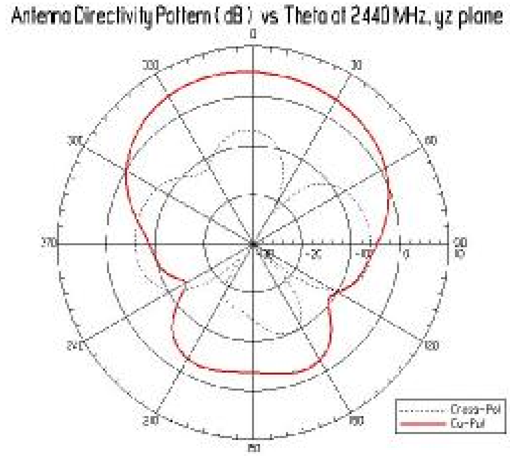


Fig. 5: E-plane pattern of the elliptical DRA at 2.44GHz

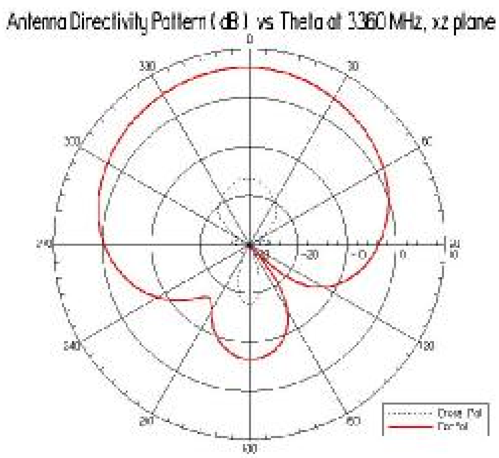


Fig. 6: E-plane pattern of the elliptical DRA at 3.36 GHz

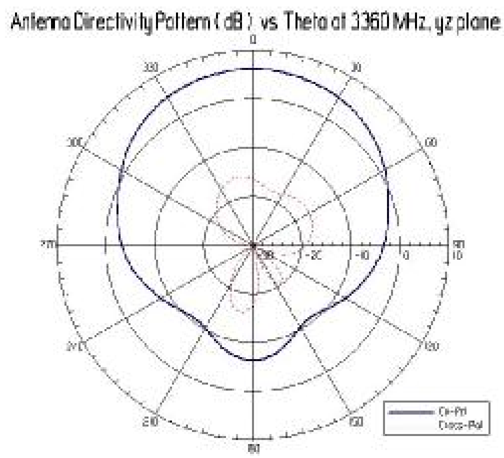


Fig. 7: H-plane pattern of the elliptical DRA at 3.36 GHz