OCTAGONAL MICROSTRIP PATCH ANTENNA FOR DUAL BAND APPLICATIONS

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ABSTRACT

A dual port dual polarized octagonal microstrip patch antenna suitable for dual band applications is discussed theoretically and experimentally. The antenna exhibits good impedance bandwidth, gain and broad radiation patterns. Parameters predicted by the Conformal Finite Difference Time Domain algorithm show good agreement with the simulated results and experimental observations.

INTRODUCTION

The recent boom in wireless communication industry, especially in the area of cellular telephony and wireless data communication, has lead to the increased demand for multi band antennas. Polarization diversity is a desirable characteristic in such an application. Multilayer substrate configuration, addition of parasitic elements, reactive elements, perturbing the antenna geometry etc are the methods adopted to achieve multi band operation. Dual frequency operations can be realized by exciting the Microstrip Patch Antenna (MPA) using a single feed [1] or dual feed [2]. Dual band dual port dual polarized octagonal patch antenna exhibiting with good reflection and radiation characteristics in the desired dual bands is discussed numerically and experimentally. The dual bands presented include DCS(1800)-PCS(1900),DCS(1800)-Bluetooth, DCS(1800)-UMTS and GPS-PCS(1900). The moderate 2:1 VSWR bandwidth, isolation between the two ports and reduced area compared to conventional circular patches are striking features of the geometry. Proximity coupling methods allow easy feed design and impedance matching. Conformal Finite Difference Time Domain technique[3], with Perfect Magnetic Conductor (PMC) applied along the wall of symmetry[4-5], is used to study the characteristics numerically. The theoretical results are compared against experimental values and IE3D™ simulation results.

ANTENNA GEOMETRY

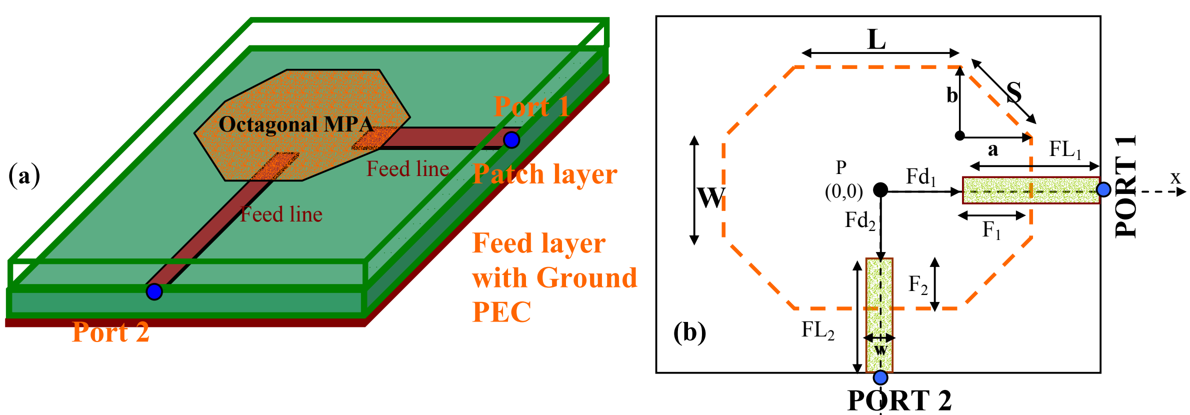


Fig.1 The Octagonal Microstrip patch antenna configuration
(a) Dual port Octagonal patch antenna layout with electromagnetically coupled feed lines.(b) Top view of the feed layer

The geometry of the *Octagonal* MPA is illustrated in fig.1. It consists of an octagonal patch with length, L width, W and slant edge of dimension, S (constitutive dimensions being *a,b*).The geometric centre of the patch is denoted as P. The patch is etched on a substrate of thickness, h and dielectric permittivity, ε_r. Octagonal patch antenna resonates at two frequencies determined primarily by the L and W dimensions of the geometry. The dimension S serves as an additional parameter that helps in trimming the resonant frequencies to the desired value. It also serves to achieve beam shaping. The dual port dual frequency Octagonal MPA is excited by *Electromagnetic coupling* using two orthogonal 50Ω microstrip feed lines as illustrated in fig.1.a. The top view of the feed layer configuration is illustrated in fig.1.b.The feed lines for Port 1 and Port 2 are of lengths FL_1 and FL_2 respectively. Fd_1 and Fd_2 indicate the distance between *open end* of the feed lines and geometric centre P, of the patch. The feed – patch overlap distance, F_1 and F_2, determines the impedance match at the respective ports.

NUMERICAL INVESTIGATION BASED ON CONFORMAL FDTD

Conformal FDTD algorithm is employed for the study and optimization of the Octagonal Microstrip Patch Antenna configuration. The CFDTD problem is set up treating the patch surface, feed lines and ground metallisation as perfect electric conductors (PEC). Fig.2 indicates the cell sizes of normal and distorted Yee cells, assigned to patch interior region and substrate region. The color bar indicates the size of the distorted cells in the computational domain, which lie along the inclined edges of the geometry. These distorted Yee cells, as shown in the fig, is given special attention based on the *conformal* scheme[3]. The feed is modeled as a resistive voltage source oriented in the positive z direction. The delayed Gaussian excitation is impressed at the feed point of the patch by assigning the distribution to an appropriate E_z component. Mur's Absorbing Boundary Conditions (ABC) are applied in the x, y and z directions at 30x30x15 cells away from the geometry. Table.1 highlights the optimized temporal and spatial parameters used in the source code developed in MATLAB™ environment for CFDTD computation. The Gaussian half width and time delay are chosen considering the highest frequency of interest. The grid size along the x and y directions in the CFDTD domain are chosen to facilitate description of the geometry with minimum discretisation error. The cell size along the z direction is chosen to ensure that FR4 substrate with thickness h=1.6mm, cell edges align with substrate boundaries in the z direction.

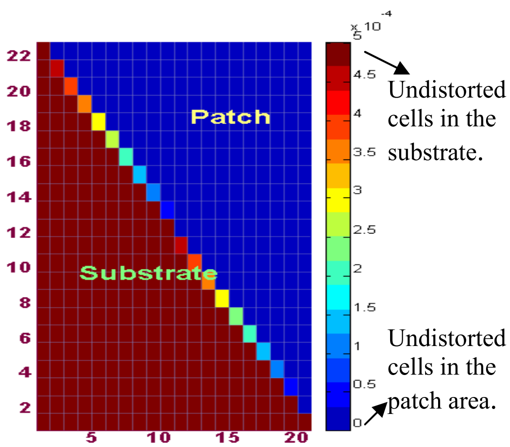


Fig.2 Inclined edge of the Octagonal Microstrip Patch Antenna showing the distorted cells of the CFDTD computation domain

Table .1 Optimized CFDTD code parameters

Temporal parameters	***Spatial parameters***
Gaussian Pulse Half width T= NΔt=21ps Time delay $\tau_d = 3T$	Undistorted Cell Dimensions Δx = 0.5mm, Δy = 0.5mm, Δz = 0.4mm (for substrate thickness h = 1.6mm)
Time step (according to CFL criteria) Δt = 0.66 ps	Distorted Cell Dimensions $\delta_x = 0$, for $\frac{\delta_x}{\Delta x} < \frac{1}{15}$ $\delta_y = 0$, for $\frac{\delta_y}{\Delta y} < \frac{1}{15}$ else the actual value is computed depending on the ratio *a/b*
Number of time steps : 4000 Simulation interval :2.64ns	

RESULTS

The octagonal microstrip patch dimensions suitable for different dual band operations are shown in table.2 along with the optimum feed lengths. Fig.3a-b shows the numerical, simulated and measured reflection characteristics of the antenna with the patch and feed lines fabricated on FR4 substrate (ε_r=4.28, h=1.6mm) for two different cases. The dual port geometry exhibits isolation characteristics better than -20 dB. The discrepancies may be due to the discretisation error in defining the geometry and uncertainty in the material parameters of the substrate. The influence of feed length on the two resonant frequencies is illustrated in fig.4.a-b. The computed, simulated and measured radiation pattern of Antenna 2 is given in fig.5a-b. The geometry offers broad radiation patterns in the broad side direction.

Table 2 Octagonal microstrip patch dimensions suitable for different dual band operations

Patch dimensions	Port 1		Port 2		Application band
	Expt	Computed	Expt	Computed	
L = 30mm, W= 20mm, a= 9mm, b=9mm, FL_1=0.541 λ_d, FL2=0.328 $\lambda_{d,}$ Antenna 1	1.57GHz 1.548GHz-1.593GHz	1.5677GHz 1.5041GHz-1.6372GHz	1.9GHz 1.881GHz-1.922GHz	1.9206GHz 1.8512GHz-1.99GHz	GPS- PCS 1900
L = 24.5mm, W = 9.5mm, a = 10mm, b = 10mm, FL_1 = 0.31$\lambda_{d,}$ FL_2 = 0.42λ_d Antenna 2	1.795GHz, 1.774GHz-1.821GHz,	1.81GHz 1.7644GHz-1.8628GHz	2.455GHz 2.422GHz - 2.5009GHz.	2.4297GHz 2.3487GHz-2.5165GHz	DCS-1800_ Bluetooth
L = 24mm, W= 21mm, a= 10mm, b=10mm, FL_1=0.307λ_d, FL2=0.328$\lambda_{d,}$ Antenna 3	1.78GHz 1.747GHz-1.803GHz	1.7702GHz 1.7124GHz-1.828GHz	1.9GHz 1.873GHz-1.93GHz	1.8975GHz 1.838Ghz-1.9611GHz	DCS-1800-PCS 1900
L = 25mm, W= 17mm, a= 9mm, b=9mm, FL_1=0.312 λ_d, FL2=0.361$\lambda_{d,}$ Antenna 4	1.81GHz 1.782GHz-1.8327GHz	1.8338GHz 1.7644GHz-1.9091GHz	2.125GHz 2.091Ghz-2.1495GHz	2.1405GHz 2.0595GHz-2.2157GHz	DCS-1800-UMTS

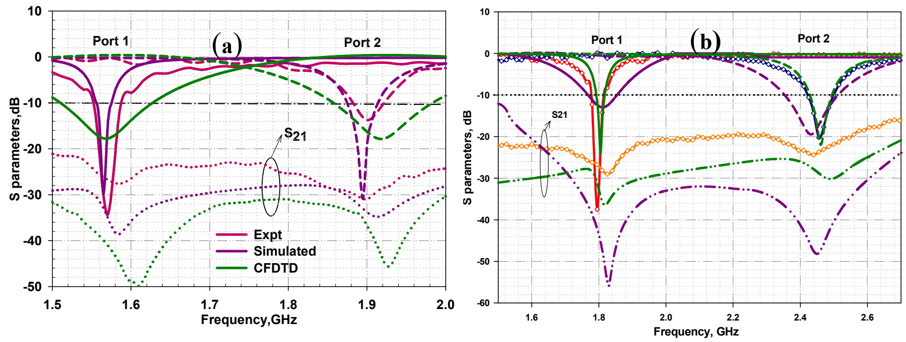
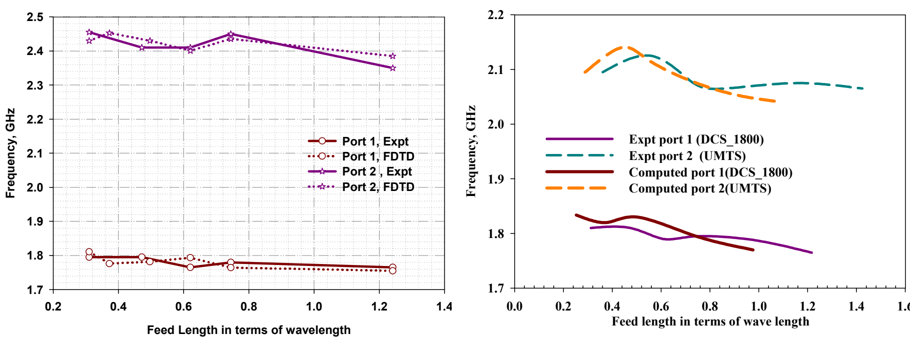


Fig 3 Computed, measured and simulated reflection characteristics of (a)antenna 1 (b) antenna 2

(**a**)
Antenna 2



(**b**)
Antenna 4

Fig 4 Effect of feed length on measured and computed resonant frequency at the ports of the Octagonal MPA

The slant edge offers additional flexibility in determining the beam width in the principal planes. The *Near field* distributions in the patch at the two resonant frequencies, computed using the CFDTD method is shown in fig 5.c. It is observed that the lower resonance band corresponds to TM_{10} mode and higher resonance band corresponds to TM_{01} mode of the geometry. The octagonal geometry offers better gain than the standard patch. In the development of a simple empirical relation, the geometry of the Octagonal microstrip patch antenna with L=W=a=b = α ,is approximated to that of an equivalent circular geometry of radius r determined as

$$r = 1.51\alpha + 0.48h \quad (1)$$

where h is the substrate thickness. The resonance frequency of the Octagonal patch is then calculated from the standard equation for computing the resonance frequency of TM_{11} mode of a circular patch of radius ‘r’. The '*h*' factor in (1) obtained empirically accounts for *the increase in the extend of fringing field due to electromagnetic coupling employed.* Table.3 shows the comparison of resonant frequency estimated using the above relation for octagonal geometry of different dimensions, in comparison with measured results for patches fabricated on FR4 substrate.

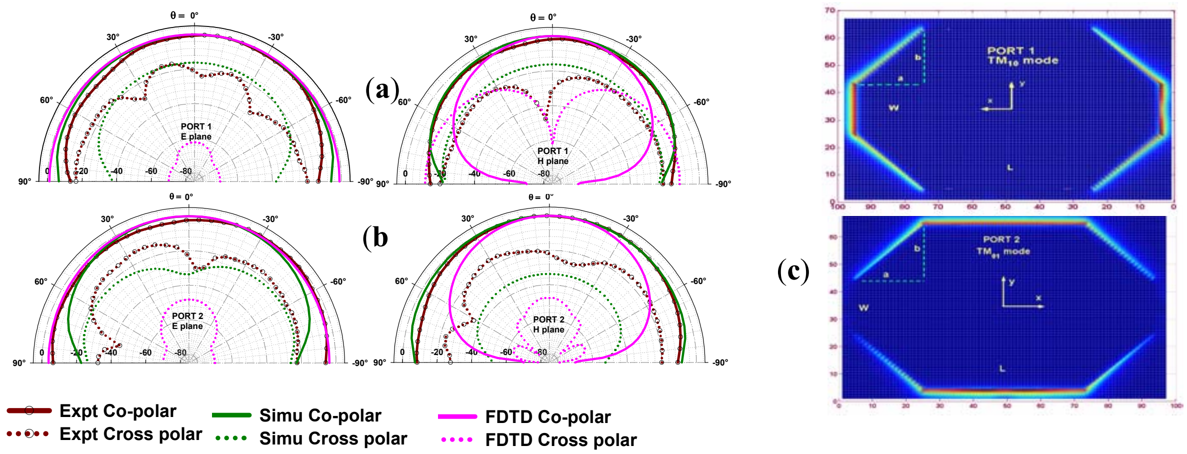


Fig.5 Computed , Measured and simulated Far field patterns and computed *Near field* distribution of antenna 2 E plane and H plane patterns of (**a**) Port 1 (**b**) Port 2 (**c**) Near field distribution at the two ports

Table 3 Variation of resonant frequency for different values of ' α ' for the Octagonal MPA

Antenna dimension α (mm)	Resonant Frequency(GHz)		
	Measured	As per (1)	Fractional error
6	4.12	4.1261	-0.148
10	2.59	2.5913	-0.05
16	1.675	1.6654	0.573
24	1.135	1.1288	0.546
34	0.812	0.80497	0.866
40	0.6933	0.68683	0.933

CONCLUSIONS

The Electromagnetically excited Octagonal microstrip patch antenna is a suitable candidate for integrated mobile communication gadgets. The antenna offers a size reduction in comparison to conventional patch antennas without causing deterioration of the radiation properties. Simple geometry , ease of excitation, moderate bandwidth, gain and broad radiation patterns are the salient features of this antenna.. Dimensions of the geometry with the slant dimension facilitating frequency and beam shaping. Since TM_{10} mode is linearly polarized along L and TM_{01} mode is linearly polarized tangential to W,array configurations may be easily realized for circular and/or elliptical polarisation by proper feed design.

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