Conformal FDTD analysis of an Octagonal Microstrip Patch antenna

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Introduction

The recent boom in wireless communication industry, especially in the area of cellular telephony and wireless data communication, has led to the increased demand for multi band antennas. In such applications the issues to be addressed are, wide bandwidth and gain, while striving for miniature geometry.

A dual frequency configuration useful in GSM1800 and Blue tooth, is one that operates with similar properties, both in terms of reflection and radiation characteristics, in the two bands of interest. Dual frequency operations can be realized by exciting the Microstrip Patch Antenna (MPA) using a single feed [1] or dual feed [2].

In this paper, Conformal FDTD[3] method with Perfect Magnetic Conductor (PMC) applied along the plane of symmetry [4] is used to study the characteristics of an Octagonal MPA. The theoretical results are compared against the experimental and IE3D™ simulated results.

Antenna Geometry

The Octagonal patch antenna excited with proximity coupling as shown in Fig. 1.a., exhibits linear orthogonal polarization with 2:1 VSWR bandwidth of 2.89% and 3.5%, resonating at 1.87GHz and 2.44 GHz respectively, to support the GSM1800 and Bluetooth frequency bands. The patch dimensions for the above configuration are shown in Fig. 1.b.

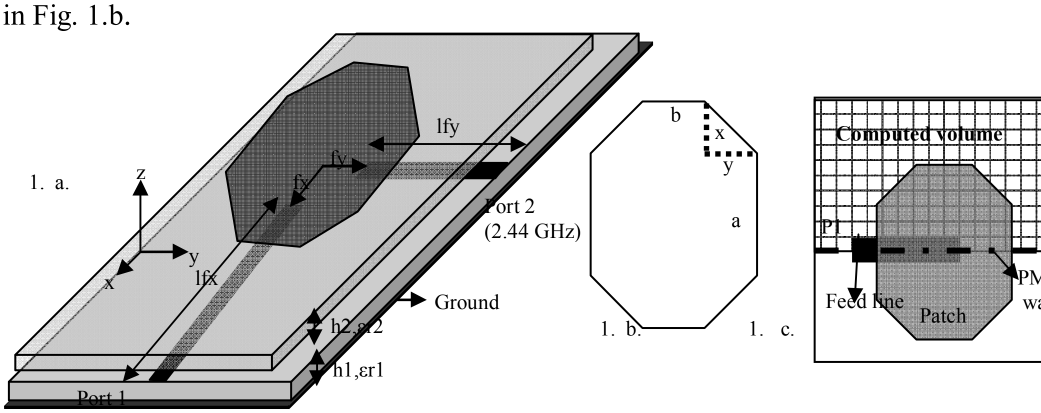

Fig. 1.a. The antenna configuration. Substrate parameters: h1=h2=1.6mm, εr1 = εr2=4.28;
Feed Offset: x offset (fx) =12.5mm, y offset (fy) =3.5mm; Feed line length lfx = lfy= 50 mm;
1. b. Patch Dimensions. a= 24mm, x =10mm, y=10mm, b=10mm.
1. c. The computational domain defined by the Perfect Magnetic Conductor (PMC) wall along the plane of symmetry, when the antenna is excited at port 1

Theoretical Investigations Based On Conformal FDTD

FDTD method is employed for the theoretical investigations of the antenna under study. The striking features of this method are its simplicity, flexibility and ease of implementation[5]. The Electric (E) and Magnetic (H) fields in the computational domain are updated based on the conformal FDTD algorithm. The PMC wall applied along the symmetry plane, as shown in Fig. 1.c, helps in reducing the computational domain to half. For analyzing the Antenna reflection characteristics, a Gaussian pulse of half width 21ps is impressed into the computational domain at the feed point corresponding to the port under study. Time is then advanced until the pulse propagates through the workspace and the fields die down to zero. The width of the pulse and the time delay are chosen to suit the frequency bands of interest. The undistorted cell sizes of 0.5mm x 0.5mm x 0.4mm are chosen so that there are more than 20 cells per wavelength in all directions. The time step is chosen as 75% of Courant stability criterion. The simulation is run for 2.64ns with time step of 0.66ps. Based on the conformal FDTD approach the H field update equation along the z direction is given as,

$$Hz(i,j,k,n+1/2)=Hz(i,j,k,n-1/2)+\Delta t/(\mu\Delta x0\Delta y0)\{Ex(i,j,k,n)\bullet\Delta x(i,j,k)-Ex(i,j-1,k,n)\bullet\Delta x(i,j-1,k)$$
$$-Ey(i,j,k,n)\bullet\Delta y(i,j,k)+Ey(i-1,j,k,n)\bullet\Delta y(i-1,j,k)\}$$

It is assumed that when Δx (or Δy) < $1/15*\Delta x_0$ (orΔy_0), Δx, $\Delta y \equiv 0$. A 50 Ω resistance is attributed to the source and detector probe points to ensure fast convergence [6]. The direct output of FDTD run is the time domain information which is then converted appropriately to frequency domain characteristics by applying Fourier transformation.

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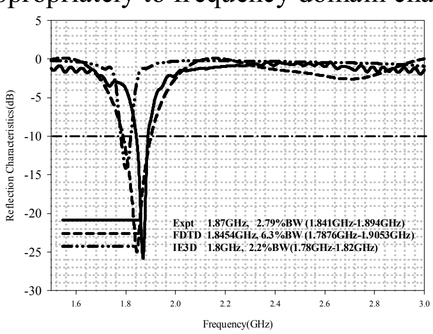
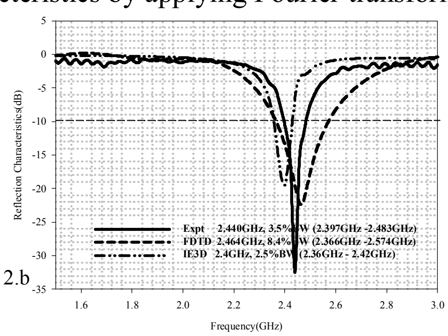


2.b



2.c

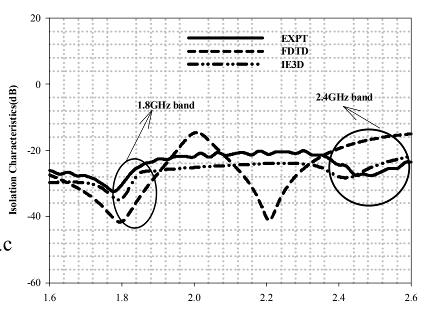


Fig. 2. Characteristics of the Octagonal patch antenna.
Return loss : 2.a. Excited in Port 1.
2.b. Excited in Port 2
2.c Isolation characteristics :
Expt: -24dB at 1.87GHz and -27dB at 2.44GHz
FDTD: -35 dB at 1.8454GHz and -18dB at 2.464GHz
IE3D : -35dB at 1.8GHz and -28dB at 2.4GHz

The Input impedance of the antenna is computed as ratio of the FFT of voltage derived from E field values at the feed point, over the entire time steps, to the FFT of current at the same point, derived from the H field values. Reflection Coefficient S_{11} (in dB) is then computed. The Isolation characteristics is calculated from the voltage induced on a 50 Ω resistance at feed point 2, derived from the H field values, and the voltage impressed at feed point 1. The Reflection and Isolation characteristics of the antenna obtained from

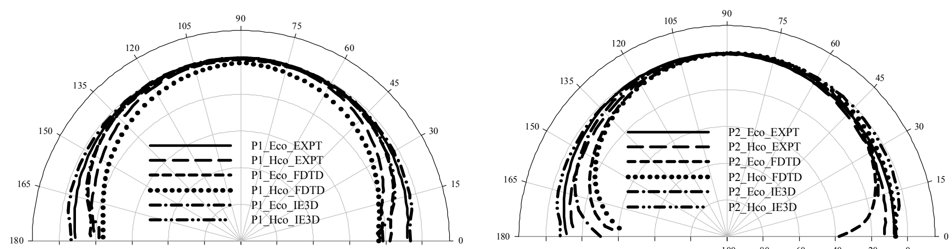
FDTD calculation, experiment and IE3D™ simulation is shown in Fig. 2. Table below summarises the results. The discrepancies may be due to the discretization error in defining the geometry and uncertainty in the material parameters of the substrate.

	PORT 1				PORT 2			
	Fr (GHz)	Band (GHz)	2:1 VSWR Bandwidth	% Difference in Fr wrt expt value	Fr (GHz)	Band (GHz)	2:1 VSWR Bandwidth	% Difference in Fr wrt expt value
Expt	1.87	1.841 - 1.894	2.79	--	2.440	2.397 - 2.483	3.5	--
FDTD	1.8454	1.7876 - 1.9053	6.3	-1.315	2.464	2.366 - 2.574	8.4	+0.98
IE3D	1.8	1.78 - 1.82	2.2	-3.7	2.4	2.36 - 2.42	2.5	-1.64

A sinusoidal excitation is used to address the radiation problem. The excitation frequencies chosen for Port 1 and 2 respectively are 1.8454 GHz and 2.464 GHz, based on the reflection characteristics of the antenna. Iteration is carried out until the system achieves sinusoidal steady state. An aperture is defined in a layer above the patch surface, and at each spatial point Q in this plane, the time independent first harmonic coefficient E(x',y',z=0) is computed by sampling the tangential field components over N time steps corresponding to one period of the excitation.

$$E(x',y',z=0) = (1/N)\sum_{n=1}^{N} E(n) \bullet \exp(j2\pi.n/N)$$

where, E(n) corresponds to the instantaneous tangential E field component Exn or Eyn at Q(x',y',0).



(3a) Port1 (3b) Port2

Fig. 3.Radiation Patterns of the Octagonal patch antenna described in Fig. 1
Co_polar Patterns in the E and H planes at (3.a) Port1 resonance. (3. b) Port2 resonance

From the aperture field so computed the Magnetic surface current density is derived [7] and used to compute the electric vector potential **F** [equation 1.9 [6]] over the aperture. Assuming $e^{j\omega t}$ time variation, Electric field at a far field point P (r, θ, φ) in free space with characteristic impedance η_0 is computed as , $E = j\omega.\eta_0.(F_\theta.a_\phi - F_\phi.a_\theta)$ .The far field components E_θ and E_φ are derived by the rectangular to spherical transformation. Assuming that, the antenna radiates into the z >0 region, from the aperture in the z = 0 plane, with the transverse electric fields are negligible outside the aperture region,field equation at a far field point r (r »$(x'^2+y'^2)^{1/2}$) becomes

$$E = j.\exp(-jkr)/(\lambda.r) \bullet \left(\begin{pmatrix} Cos(\theta).(f_x.Cos(\phi) + f_y Sin(\phi))a_\phi \\ -(f_x.Sin(\phi) - f_y.Cos(\phi))a_\theta \end{pmatrix} \right)$$

where

$$f_* = \iint_S E_*(x',y',0)\exp\left(jk \begin{pmatrix} x' Sin(\theta).Cos(\phi) + \\ y' Sin(\theta).Sin(\phi) \end{pmatrix} \right) \bullet dx'dy'$$

and S is the planar aperture selected. The normalized co-polar far field patterns ($E(\theta)$ and $E(\varphi)$) thus computed for the two ports at their resonance frequencies, in the E and H planes (at $\varphi = 0^o$ and 90^o) are shown in Fig. 3., along with the experimental observations and IE3D™ simulation results. The Electric filed distributions (x and y components) on the patch at the two resonant frequencies are shown in Fig. 4. It shows that 1.8 GHz corresponds to TM_{10} mode and 2.4 GHz corresponds to TM_{01} mode of the geometry. The relative gain of the proposed antenna in the two frequency bands of operation, in comparison to that of standard circular patch antenna, is shown in Fig. 5. In most of the band of operation the gain of the antenna is greater than circular patch antenna operating at the same band.

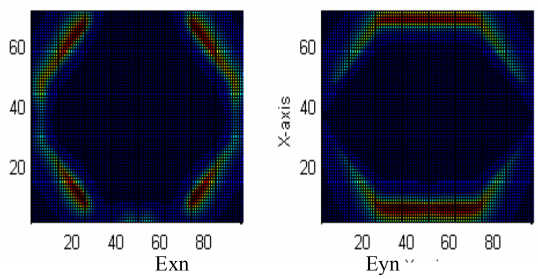


Fig. 4 Tangential Electric field components computed using FDTD

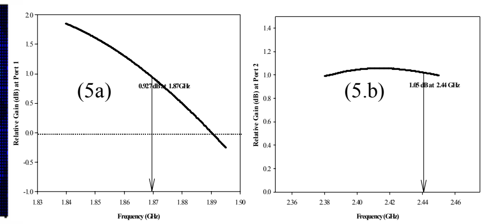


Fig. 5 Measured Gain at port 1 and port 2 resonances.

Conclusions

The Conformal FDTD analysis of the dual band dual polarized octagonal patch antenna is presented. During the study it is observed that selection of feed length feed offset from the geometric centre of the patch causes only slight variations in the characteristics. The antenna exhibits gain comparable to that of standard circular patch and is highly suitable for GSM and Bluetooth applications.

References:

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