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Conference Paper · October 2010

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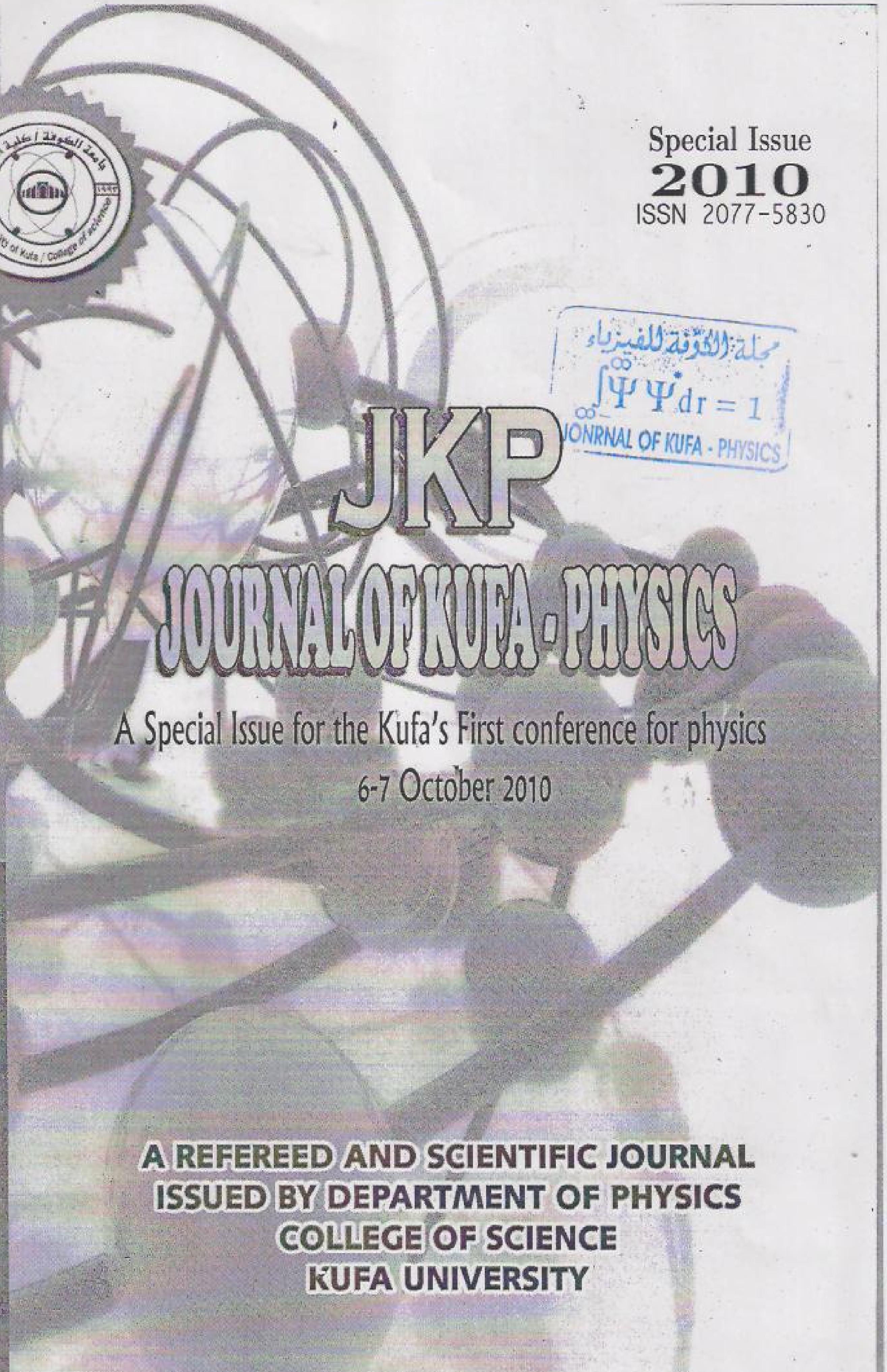

Special Issue
2010
ISSN 2077-5830

JKP

JOURNAL OF KUFA - PHYSICS

A Special Issue for the Kufa's First conference for physics

6-7 October 2010

**A REFEREED AND SCIENTIFIC JOURNAL
ISSUED BY DEPARTMENT OF PHYSICS
COLLEGE OF SCIENCE
KUFA UNIVERSITY**

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ABSTRACT

The method of moment (MoM) technique with Galerkin approach is applied as a numerical technique to predict the induced current on the surface and calculate the radiation fields of a spherically capped metallic biconical antenna excited by electromagnetic pulse.

This antenna is considered as a body of revolution having an equal or unequal cone angles. Good agreement has been obtained between the predicated results and those reported by other research workers.

Keyword:- Antenna , Body of Revolution (BoR) , Biconical antenna

INTRODUCTION

For many years most standered called for the use of a half wave dipole antenna set for frequencies above 80 MHz. However to reduce test time, broadband antennas such as the biconical antenna and log periodic antenna began to be accepted. The biconical antenna consists of an arrangement of two conical conductors, which is driven by potential, charge, or alternating magnetic field (and the associated alternating electric current). The conductors have a common axis and vertex. The two cones face in apposite directions.

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Determination of Radiation Fields of Biconical Antenna as a BoR

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Biconical antenna are broadband dipole and widely used in automated EMC measurements in the frequency range of 30MHz to 300MHz

The biconical antenna analysis provided by Schelkunoff [1], Smith [2], Tai [3], papas and King [4] and Sandler and King [5] are generalized in this paper by considering axially symmetric bicones as a body of revolution (BoR) having equal or unequal cone angle (ψ_1,ψ_2). The structure is positioned in the spherical geometry (r,θ,ϕ) as shown in fig.(1). The body of revolution is a three-dimensional object which is formed by rotating a planner, called the generating arc, about the axis of symmetry. This rotational symmetry reduced the problem from the three-dimensional case to a series of two-dimensional problem. This result is a considerable saving both the time of computation and memory storage [6]. In this paper the influence of the variation of cone angles, which yield to change the diameter of the aperture (cap) of the cones for different length on the radiation fields are studied.

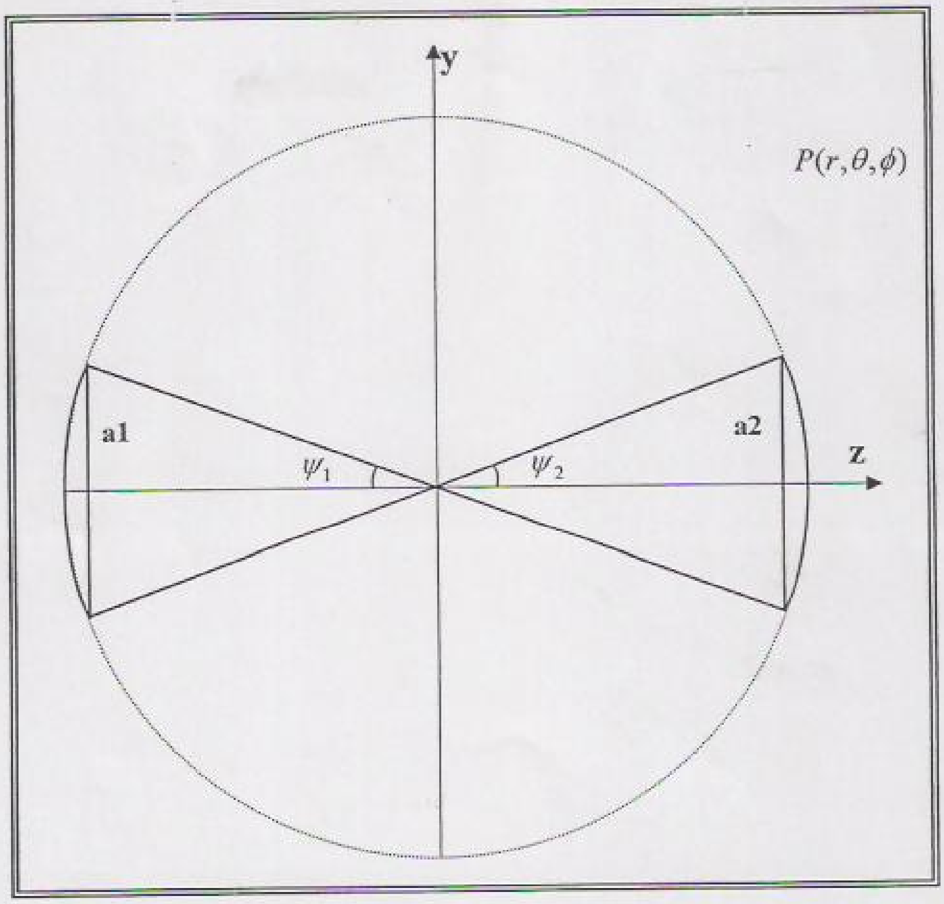


Fig.(1): Body of revolution and Coordinate system

FORMULATION OF PROBLM

In the scattering from conducting bodies problem; the total field $\overline{E}$ is the sum of the impressed field $\overline{E}^i$ and the scattered field due to currents on the body $\overline{E}^s$, that is

$$\overline{E} = \overline{E}^i + \overline{E}^s \quad \text{..................(1)}$$

This $\overline{E}^s$ can be expressed in terms of the magnetic vector potential $\overline{A}$ and the electric scalar potential ϕ as:

$$\overline{E}^s = -j\omega\overline{A} - \nabla\phi \quad \text{..................(2)}$$

The boundary condition requires that the tangential component of total $\overline{E}$ vanish on the surface S, Hence

$$\overline{E}^i{}_{\tan} = -\overline{E}^s{}_{\tan} \quad \text{..................(3)}$$

These components can be given in term of integro - differential operators defined $L(\overline{J})$ on the BoR, that is:

$$L(\overline{J}) = \left[j\omega\overline{A} + \nabla\phi\right]_{\tan} = \frac{j\omega\mu}{4\pi}\int_s \overline{J}(\overline{r}')G(\overline{r},\overline{r}')ds + \frac{j\nabla}{4\pi\omega\varepsilon}\int_s \nabla'\cdot\overline{J}(\overline{r}')G(\overline{r},\overline{r}')ds \quad \text{..............(4)}$$

Where $G(\overline{r},\overline{r}')$ is the green function. The solution of eq.(4) gives the current $\overline{J}$ on the surface S. To select the solution of eq.(4) we use the method of moments related to Galerkin approach. The procedure approximates eq.(4) by a matrix equation $[Z_n][I_n]=[V_n]$, this matrix so obtained a generalized impedance matrix for the body $[Z_n]$. The excitation of the body is represented by a voltage matrix $[V_n]$, and the resultant current on the body is represented by a current matrix $[I_n]$.

The impedance matrix of the body is defined as:

$$Z_n = \begin{bmatrix} [Z_n^{tt}] & [Z_n^{t\phi}] \\ [Z_n^{\phi t}] & [Z_n^{\phi\phi}] \end{bmatrix} \quad \text{..................(5)}$$

The Z sub-matrix are given by[7];

$$\left(Z_n^{tt}\right)_{ij} = \sum_{p=1}^{4}\sum_{q=1}^{4}\left[j\omega\mu T_p T_q \left(\sin(\upsilon_p)\sin(\upsilon_q)\frac{G_{n+1}+G_{n-1}}{2} + \cos(\upsilon_p)\cos(\upsilon_q)G_n \right) + \frac{1}{j\omega\varepsilon} T'_p T'_q G_n \right]$$

$$\left(Z_n^{t\phi}\right)_{ij} = \sum_{p=1}^{4}\sum_{q=1}^{4}\left[-\omega\mu T_p T_q \sin(\upsilon_p)\frac{G_{n+1}-G_{n-1}}{2} + \frac{n}{\omega\varepsilon} T'_p \frac{T_q}{\rho_q} G_n \right] \quad \text{..................(6)}$$

$$\left(Z_n^{\phi t}\right)_{ij} = \sum_{p=1}^{4}\sum_{q=1}^{4}\left[\omega\mu T_p T_q \sin(\upsilon_q)\frac{G_{n+1}-G_{n-1}}{2} - \frac{n}{\omega\varepsilon} \frac{T_p}{\rho_p} T'_q G_n \right]$$

$$\left(Z_n^{\phi\phi}\right)_{ij} = \sum_{p=1}^{4}\sum_{q=1}^{4}\left[j\omega\mu T_p T_q \frac{G_{n+1}+G_{n-1}}{2} + \frac{n^2}{j\omega\varepsilon} \frac{T_p}{\rho_p} \frac{T_q}{\rho_q} G_n \right]$$

The i^{th} element of the α – directed component of the excitation matrix $[V_n]$ is given by **[8]**:

$$\left(\overline{V}_n^{\alpha}\right)_i = \int_{s_i} e^{-jn\phi} d\phi \int_0^N \hat{u}^{\alpha} f_i(t) \cdot \overline{E}_i(t,\phi)\rho dt \quad \text{..................(7)}$$

Where $\overline{E}_i(t,\phi) = \delta\left(\theta - \frac{\pi}{2}\right)/a$ is the field excited over the aperture S_i, $\rho f_i(t)$ is chosen as a triangular function over the i^{th} element and α denote t or ϕ. Eq.(7) can be written as:

$$\left(V_n^{\alpha}\right)_i = a_n U_i^{\alpha} \quad \text{..................(8)}$$

Where a_n are aperture coefficients given by **[9]**:

$$a_n = \int_{s_i} e^{-jn\phi} d\phi \quad \text{..................(9)}$$

and

$$U_i^{\alpha} = \begin{cases} U_i^{t} = \int_0^N f_i(t)\delta(\theta - \pi/2)dt \\ U_i^{\phi} = \int_0^N - f_i(t)\delta(\theta - \pi/2)dt \end{cases}$$

Here $f_i(t) = \frac{1}{\rho}$, $dt = \pm\rho d\theta$ and $\theta = \frac{\pi}{2}$

So:

$U_i^{\alpha} = 1$ ....(10)

For simplicity, the computations have been made for excitation independent of ϕ which excites the n=0 mode only. This gives rise to $[Z_0^{t\phi}] = [Z_0^{\phi t}] = 0$, $[V_0^{\alpha}]_i = 2\pi$ on the slot of excitation and zero otherwise.

The total surface current (on the surface of the body) can be found from the resultant matrix current $[I_n]$ as the sum of the modal current as:

$$\bar{J} = \sum_j I_j \bar{J}_j \quad ....(11)$$

And the total radiation field $\bar{E}_u$, at a distance r from the origin, due to this current is the sum of the model filed, that is:

$$\begin{aligned} \bar{E} \cdot \hat{u} &= -\frac{j\omega\mu}{4\pi r} e^{-jkr} \sum_n [R_n][I_n] \\ &= -\frac{j\omega\mu}{4\pi r} e^{-jkr} \sum_n [R_n][Y_n][V_n] \end{aligned} \quad ....(12)$$

Where n denoted the mode, u is θ or ϕ, $[Y_n] = [Z_n]^{-1}$ and $[R_n]$ is the radiation transfer matrix expresses the relationship between the current on the body and the plane wave coming from (θ, ϕ) directions;

$$\begin{aligned} (R_n^{t\theta})_i &= \sum_{q=1}^{4} C_q \left[\sin(\upsilon_q)\cos(\theta_r)\left(J_{(n+1)} - J_{(n-1)}\right) + 2j\cos(\upsilon_q)\sin(\theta_r) J_n\right] \\ (R_n^{\phi\theta})_i &= \sum_{q=1}^{4} jC_q \cos(\theta_r)\left(J_{(n+1)} + J_{(n-1)}\right) \\ (R_n^{t\phi})_i &= \sum_{q=1}^{4} -jC_q \sin(\upsilon_q)\left(J_{(n+1)} + J_{(n-1)}\right) \\ (R_n^{\phi\phi})_i &= \sum_{q=1}^{4} C_q\left(J_{(n+1)} - J_{(n-1)}\right) \end{aligned} \quad .... (13)$$

Where

$C_q = \pi j^{n+1} T_q e^{jkz_q \cos(\theta_r)}$

So the total radiation field eq.(12) can be written as;

$$E_\theta = -\frac{j\omega\mu}{4\pi r} e^{-jkr} \left[R_0^{t\theta}\right]\left[Y_0^{tt}\right]\left[V_0^{t}\right] \quad \textit{for } \theta - \textit{polarization}$$

and .... (14)

$$E_\phi = -\frac{j\omega\mu}{4\pi r} e^{-jkr} \left[R_0^{\phi\phi}\right]\left[Y_0^{\phi\phi}\right]\left[V_0^{\phi}\right] \quad \textit{for } \phi - \textit{polarization}$$

RESULTS:

The coaxial biconical antenna affords a straightforward illustration of the technique. The structure is positioned in the spherical geometry as in fig.(2), and yields two concentric circles.

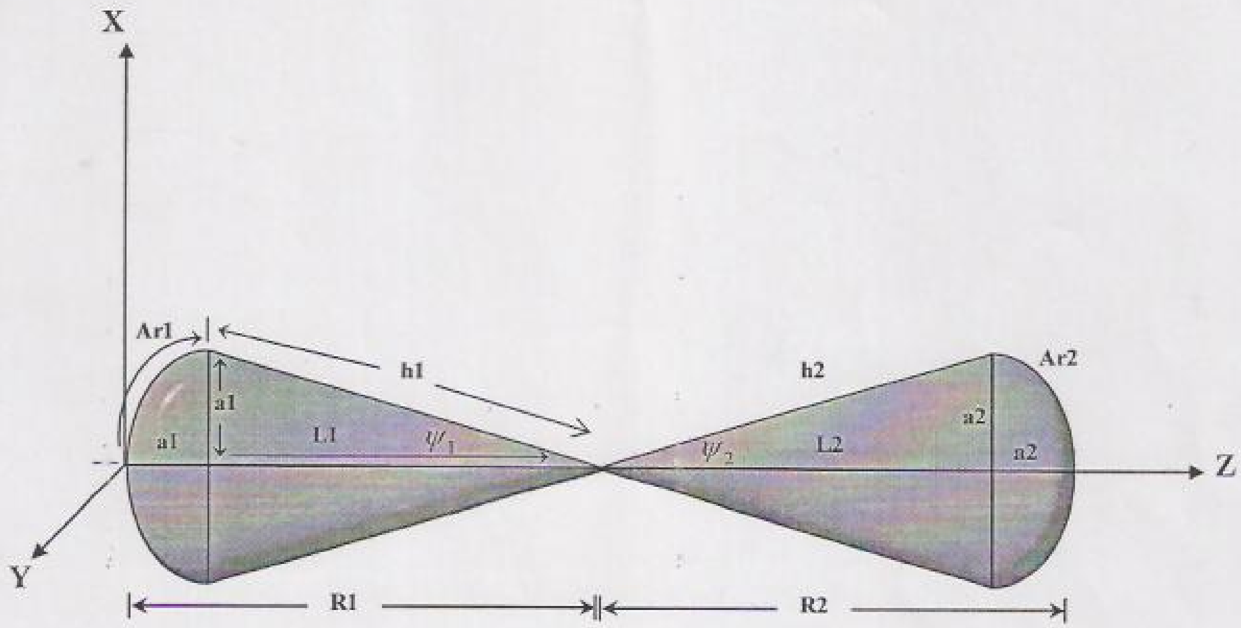


Fig.(2): Biconical antenna (BoR) has an equal cone angle

It is instructive to consider first the case of biconical with two equal angles, lengths and radius of the circles. Fig.(3) shows the absolute values of the surface current for the above characteric ($\psi_1 = \psi_2 =$, $L_1 = L_2 = 0.65\lambda$, $a_1 = a_2 = 0.1\lambda$) but with different excited slot location.

There are many parameters studied here to make sense about the contribution of the body part to the radiation field. These parameters are the body length (R_1, R_2)and sphere radius (a_1, a_2), and the values of the cone angles ψ_1 and ψ_2.

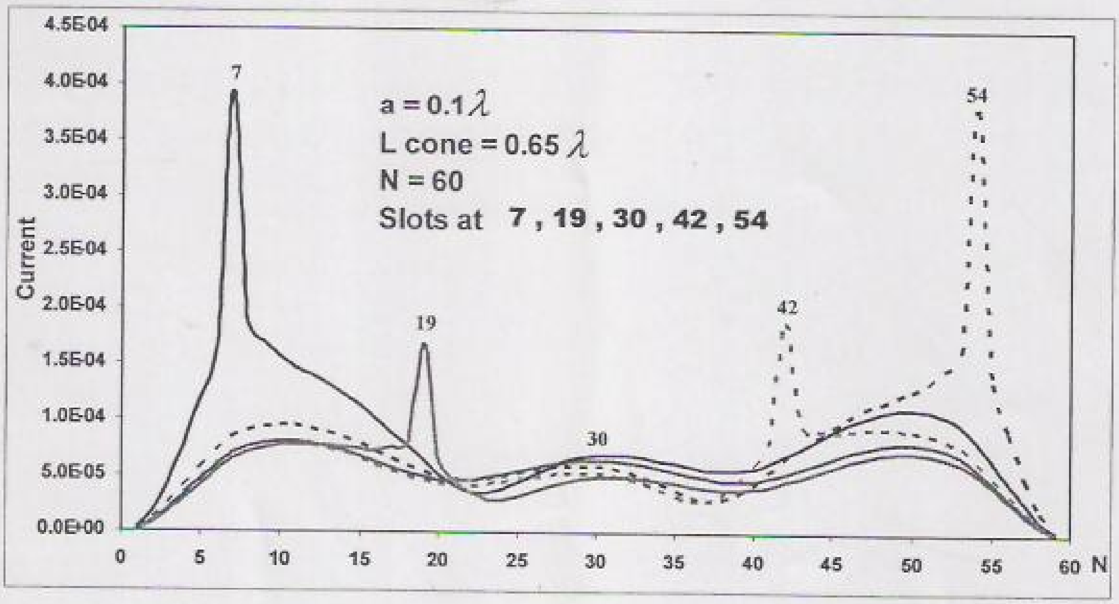
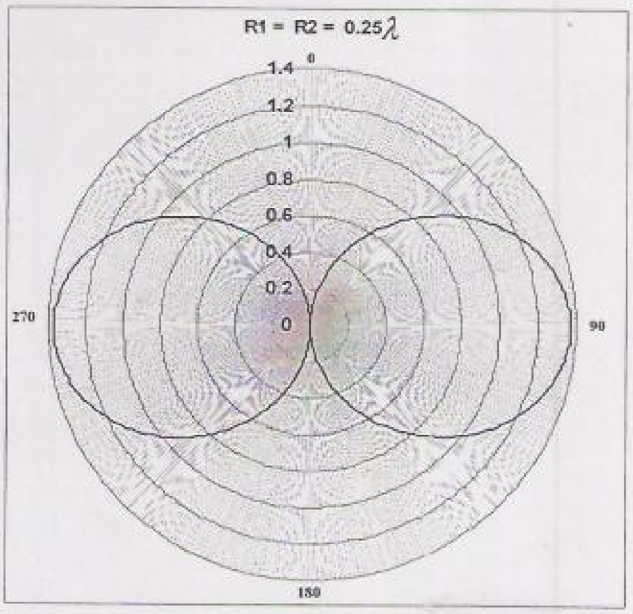
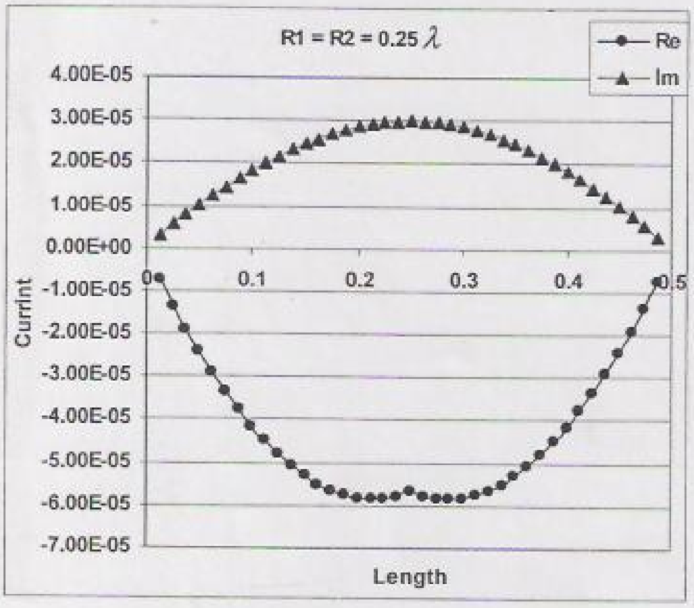
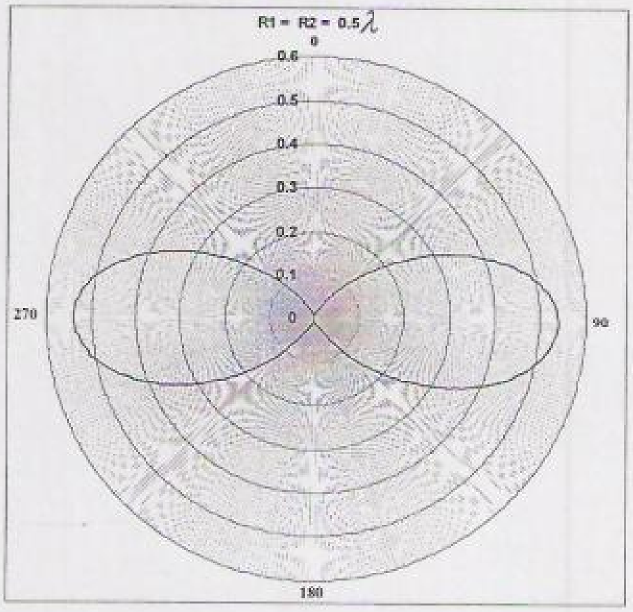


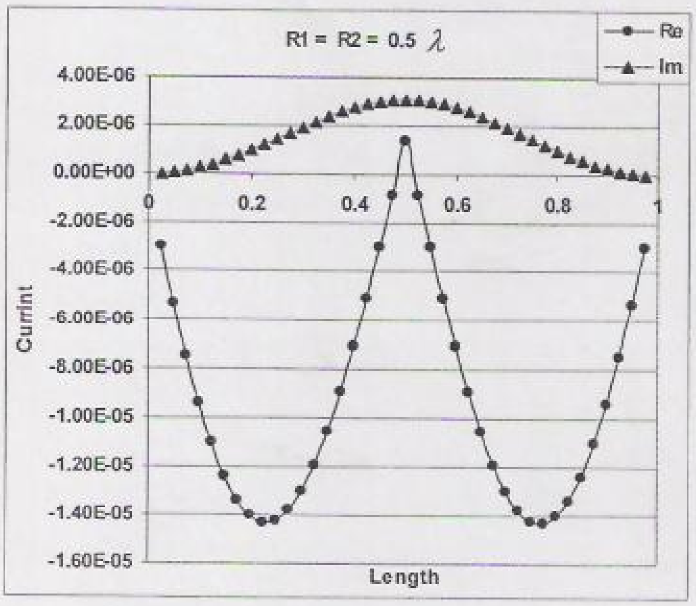
Fig.(3): Tangential component for the (or coefficients of) surface current distribution for different excited slot location.

The formulation of this study can be applied to the wire antenna, by reducing the radius of the cone to very small value, to determine the current distribution on the wire and the power gain components in the far field. A conducting biconical antennas of rounded ends of one half wavelength and its multiplication with radius equal to (0.001λ) fed of the middle is used as a body of revolution to compute the unknown current expansion coefficient and then the power gain components using MoM procedure. Fig.(4) shows the power gain pattern and the current distribution on the wire for a half wavelength, one wavelength, one and half wavelength and two wavelength wire antenna (line source). It is shown from this figure that the hypothesis led to very good agreement results with those found by other well-known method clarify in the literature.


R1 = R2 = 0.25λ
0
270
90
180


R1 = R2 = 0.25 λ
Re
Im
Currint
Length


R1 = R2 = 0.5λ
0
270
90
180


R1 = R2 = 0.5 λ
Re
Im
Currint
Length

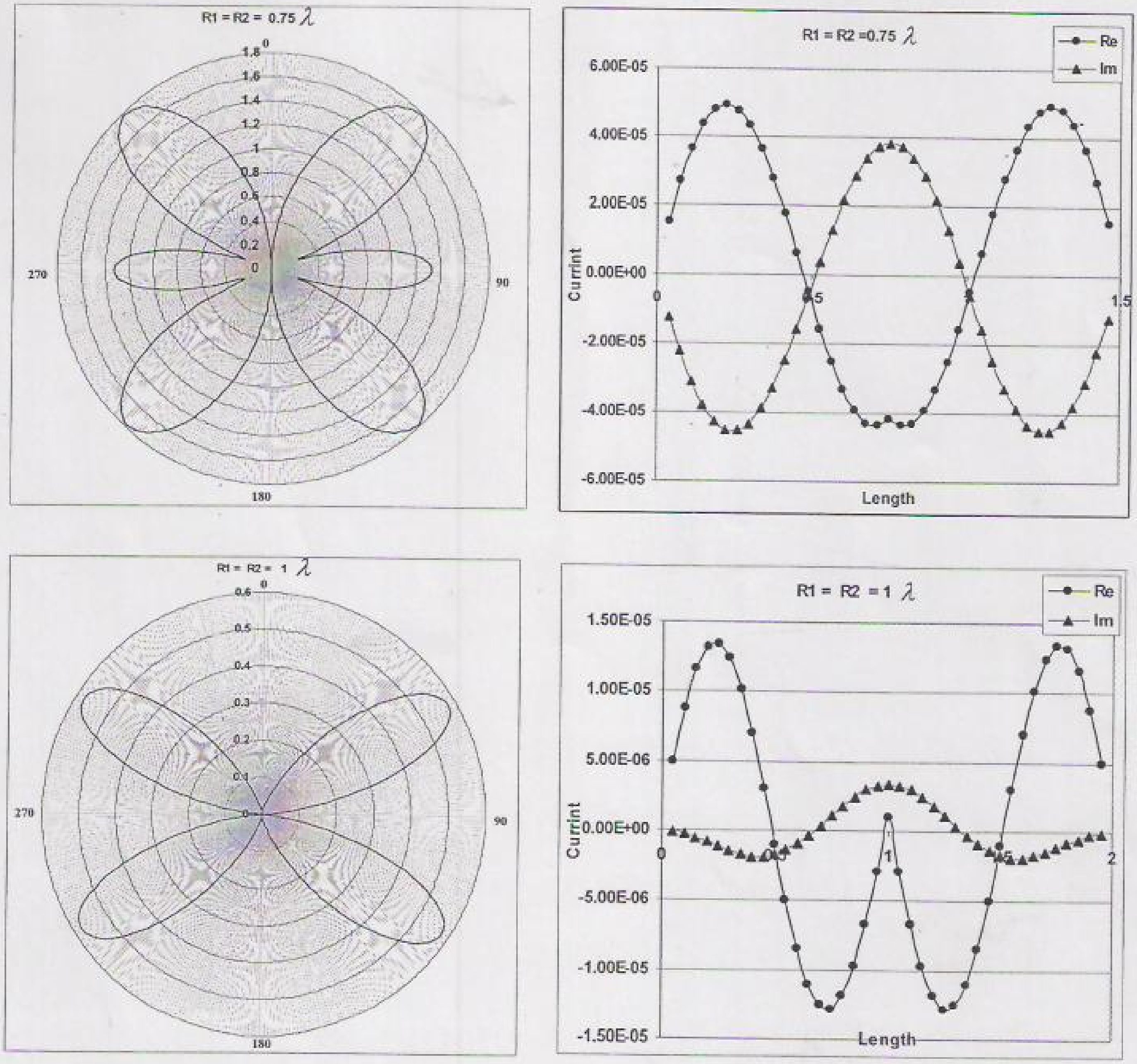
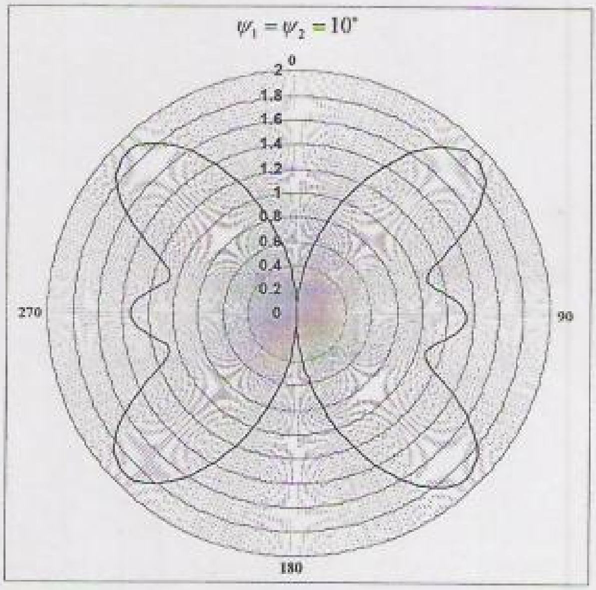


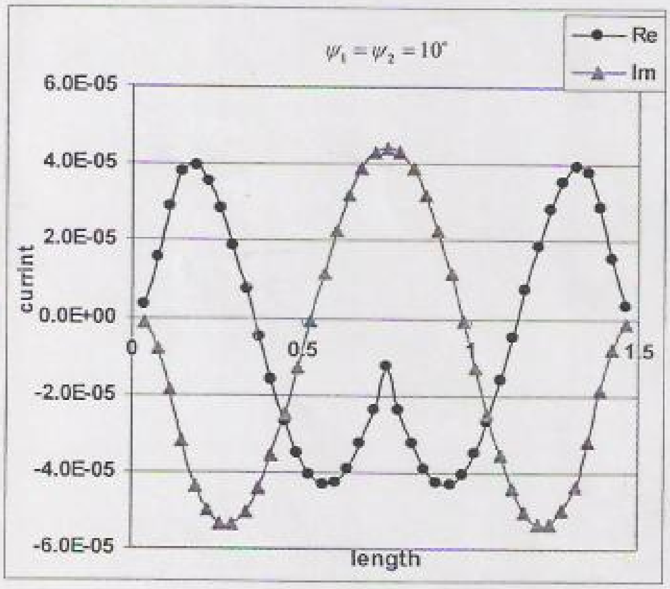
Fig.(4): Radiation patterns and surface current distribution for the wire antenna of different lengths

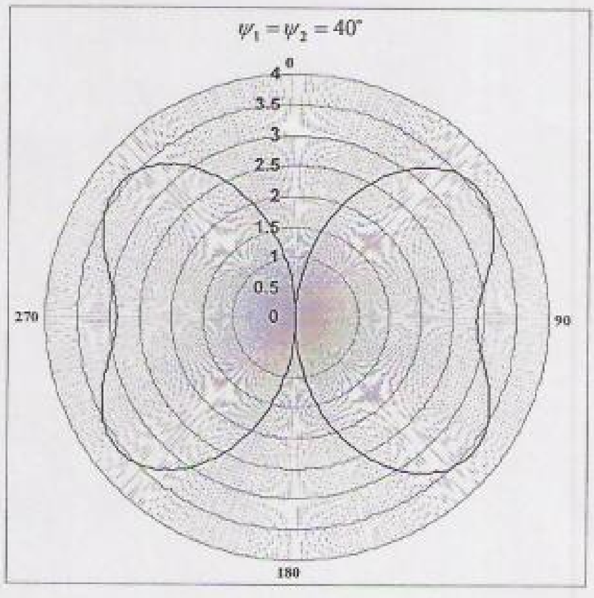
Furthermore, for biconical antenna with equal cone angles and 1.5λ length, predicted in table (1), the power gain pattern and current distribution are plotted, as in fig.(5). It is shown from the figure that the lobes of the pattern disappear and the beak of the current increased as the angles increased.

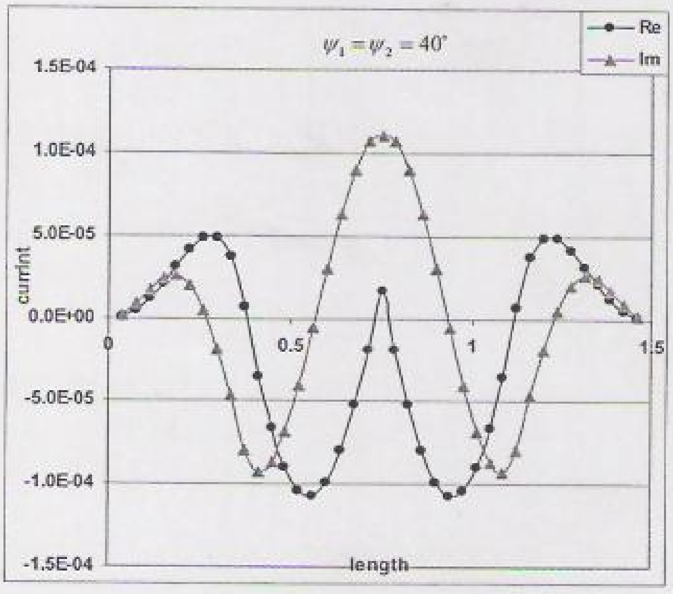
	$\psi 1$	$\psi 2$	a1	a2	L1	L2	Length
1	5	5	0.0604	0.0604	0.6896	0.6896	1.5
2	10	10	0.1124	0.1124	0.6375	0.6375	1.5
3	20	20	0.2001	0.2001	0.5498	0.5498	1.5
4	30	30	0.2745	0.2745	0.4755	0.4755	1.5
5	40	40	0.3422	0.3422	0.4078	0.4078	1.5
6	45	45	0.375	0.375	0.375	0.375	1.5
7	50	50	0.4078	0.4078	0.375	0.375	1.5
8	60	60	0.4755	0.4755	0.2745	0.2745	1.5
9	70	70	0.5498	0.5498	0.2001	0.2001	1.5
10	80	80	0.6375	0.6375	0.1124	0.1124	1.5

Table (1): The dimension of biconical with two equal angles









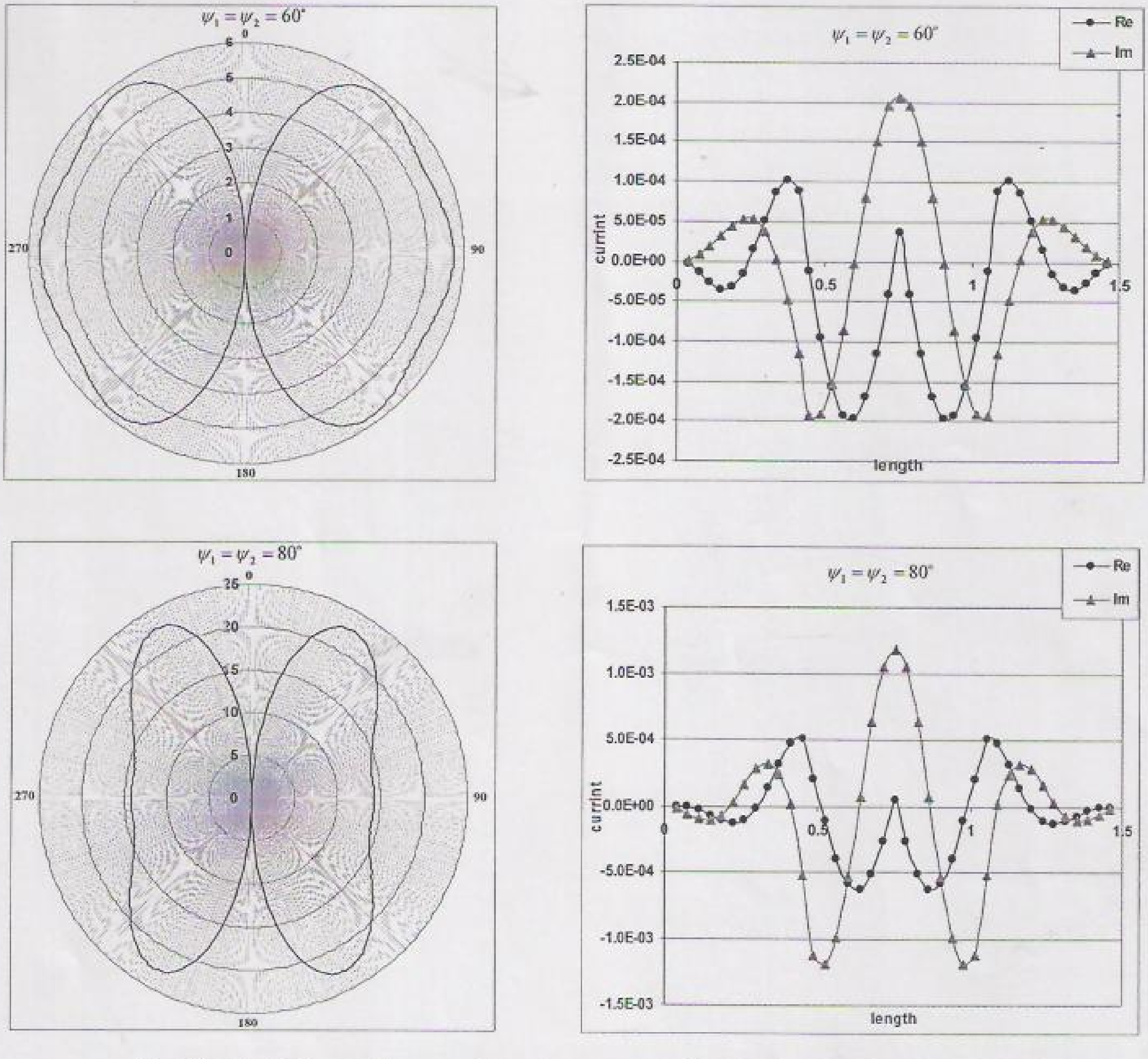
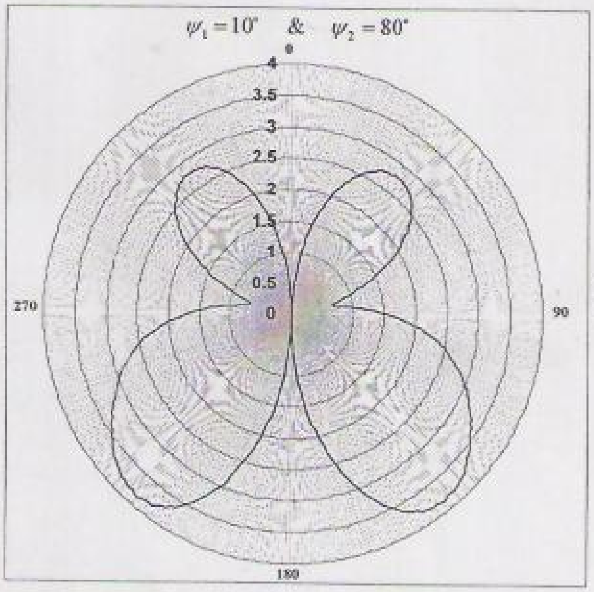


Fig.(5): Radiation patterns and surface current distribution for the biconical with two equal angles

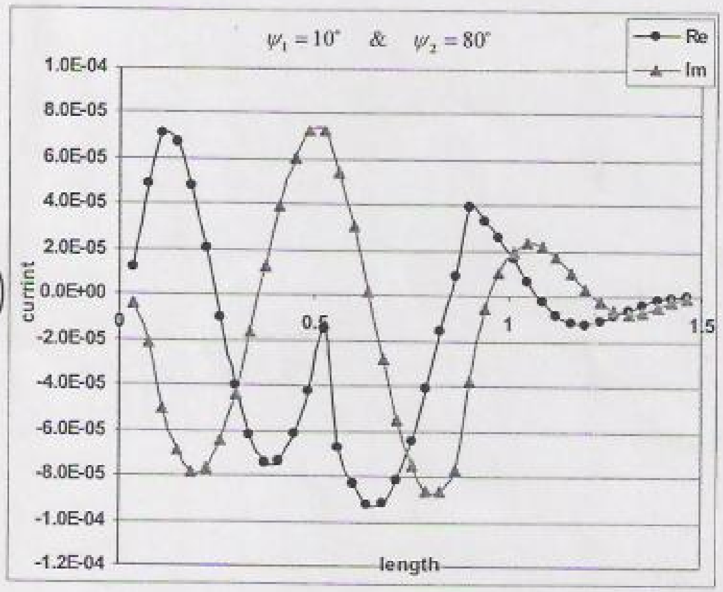
Now to illustrate the behavior for unequal angles, Fig.(6) also displays the pattern for the angles predicted in table (2).This table clarify that the cone angles, the length and the cone radius of each cone are different. This pattern has one lobe for the biconical of an approach angles fig.(6-b,c,d), and has more than one for angles of large different values (fig.(6-a)).

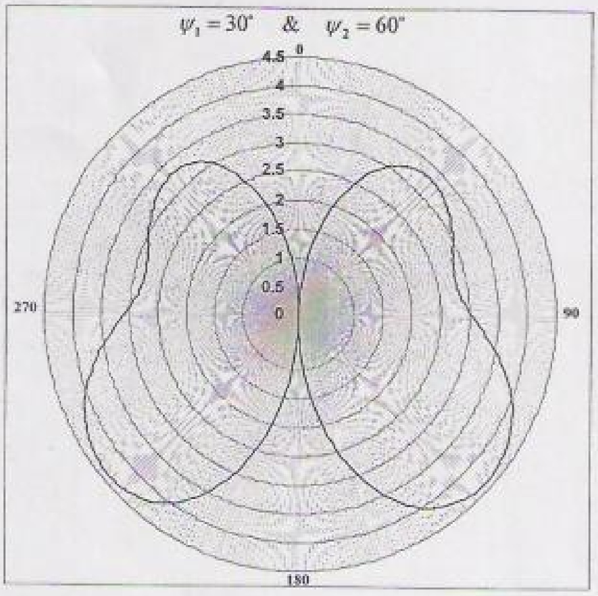
	$\psi 1$	$\psi 2$	a1	a2	L1	L2	Length
1	10	80	0.1124	0.6375	0.6375	0.1124	1.5
2	30	60	0.2745	0.4754	0.4754	0.2745	1.5
3	50	40	0.4078	0.34219	0.34219	0.4078	1.5
4	60	30	0.4754	0.2745	0.2745	0.4754	1.5

Table (2): The dimension of biconical with two unequal angles

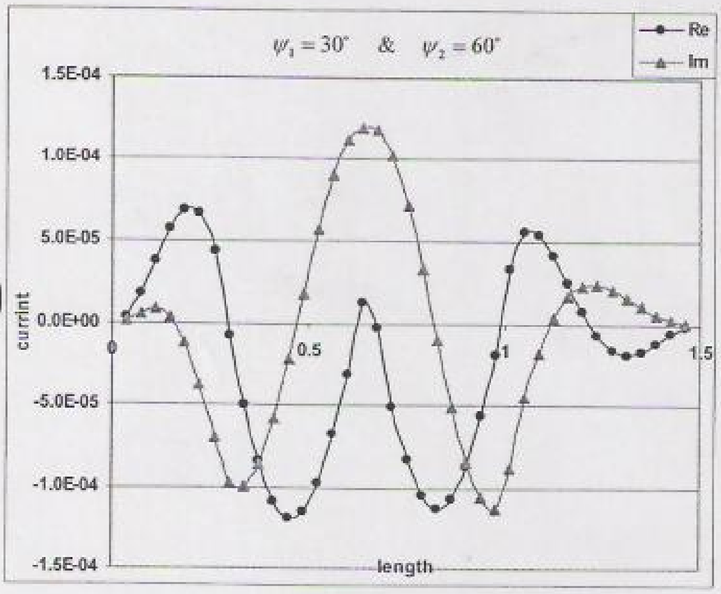


a





b



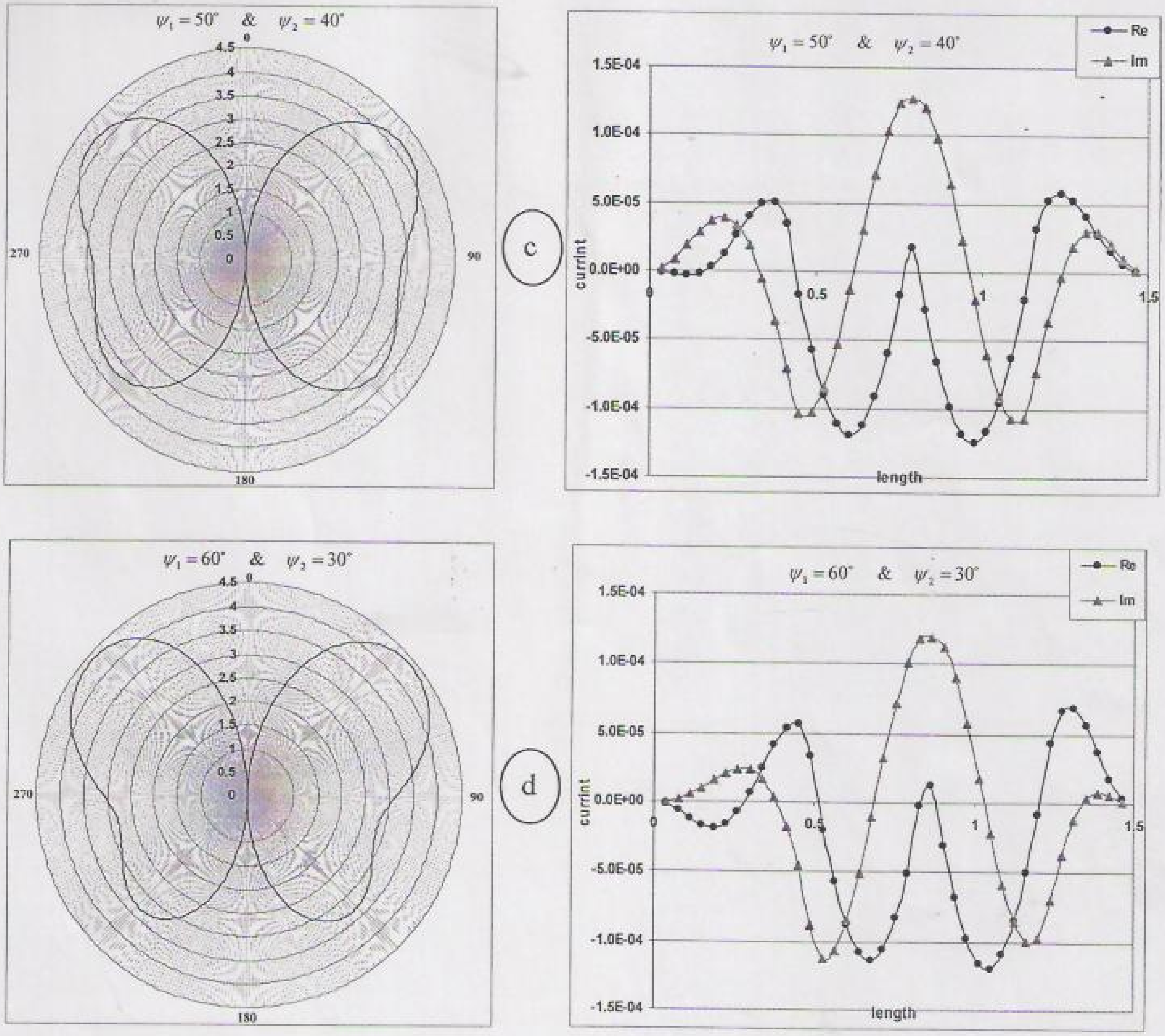


Fig.(6): Radiation patterns and surface current distribution for the biconical of unequal angles

CONCLSION

This paper has investigated the characteristic of a biconical antenna of length 1.5λ, fed in different location, of equal and unequal cone angles as a BoR. Numerical results have been presented for radiation pattern and current distribution using MoM with Galerkin technique. The resulting far field pattern are almost equal to those found with the aid of other methods.

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