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RADIATION FIELDS CALCULATION FROM WIRE ANTENNA AS BODY OF REVOLUTION (BoR)

Ranya M. Dawood[1], Ahmed H. Abood[2] and Zeki A. Ahmed[1]

[1]*Dept. of Physics, College of Science, Basrah University, Basrah, Iraq,*
zeki_abdullah @yahoo.com and ranya_alawad@yahoo.com
[2]*Dept. of Math. Dept., College of Basic Education, Misan University, Misan, Iraq,*
ahm_hash2003@yahoo.com

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ABSTRACT:

This study presents a theoretical investigation for the function of surface currents describing and radiation fields calculation for wire antenna formed through decreasing the radius of the conducting cylinder (BoR) to very small value . The hypothesis leads to very good results that match a well-known theory in the literature. This enable us to say that we introduce a new model for linear antenna parameters calculation .

Keywords: - Wire **A**ntenna , **B**ody **o**f **R**evolution (BoR)

INTRODUCTION

The problem of electromagnetic scattering and radiation by a body for revolution (BoR) has been given a great attention due to its significance in communication and radar applications. A BoR is three-dimensional object which is formed by rotating a planar curve about the axis of symmetry. By taking the advantage of the rotational symmetry of the BoR, the problem can thus be reduced from the three-dimensional case to a series of two-dimensional problems. This results in a considerable saving in both the time of computation and memory storage**[1] .** A large number of structures in the field of electromagnetic present symmetry around an axis of rotation (BoR). Among these structures there are certain types of transmission media, such as coaxial cables and cylindrical waveguides; and antennas, like wire dipoles, circular microstrip patches, cylindrical dielectric, and resonator antennas**[2].** This body of revolution approach has been applied to several numerical methods in electromagnetic ,including the method of moment (MoM), finite elements method (FEM) and the finite difference time domain (FDTM) . In this paper ,an electric field integral equation (EFIE) is formulated to treat the electromagnetic radiation problem for conducting bodies of revolution and method of moment is used together with Galerkin technique to solve this equation and calculate the radiation fields of the wire antenna .

FORMULATION OF PROBLEM:

Consider the BoR illustrated in **Fig.(1)**, where it is formed by rotating a curve, called “ generating curve ” around the z-axis which is also called the axis of BoR .

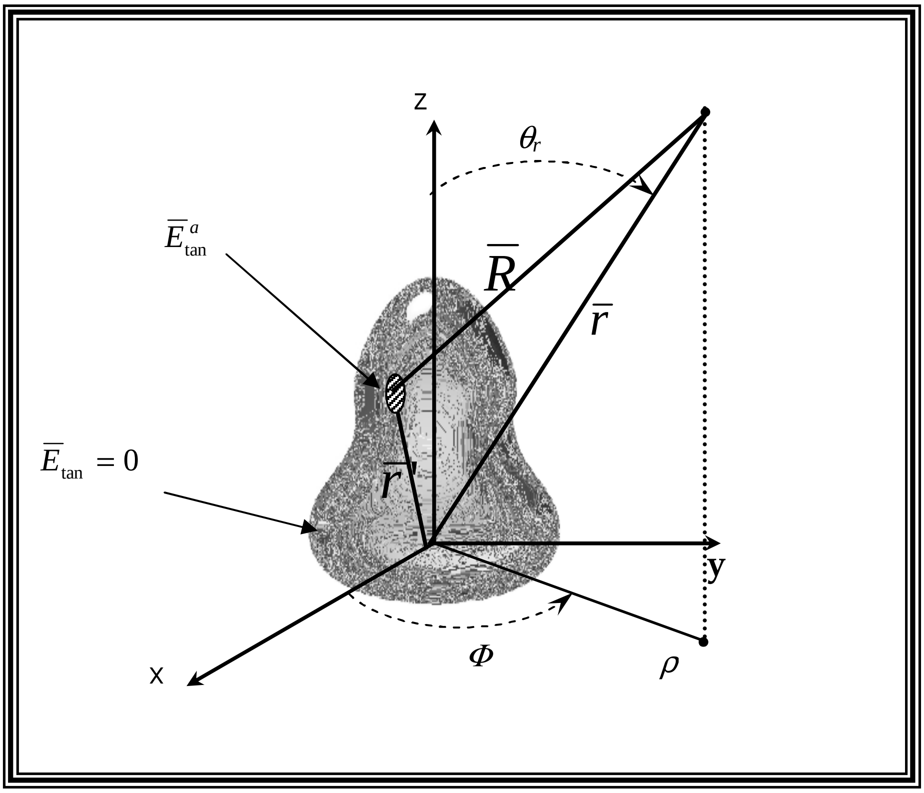


Fig.(1): Body of revolution and Coordinate system

The radiation from the perfect conductor BoR problems is assumed to become from the field on an aperture on the closed surface $\mathbf{S_i}$, called aperture electric field which has a value over the aperture and zero elsewhere just outside $\mathbf{S_i}$.

The boundary condition states that the tangential electric field must vanish on the surface **S** of the conducting :

$$-\hat{n}\times\overline{E}_{\tan}\left(\overline{J}\right)=\hat{n}\times\overline{E}^{a}_{\tan} \qquad \textbf{...........(1)}$$

Where $\hat{n}$ is the outward unit normal vector, $\mathbf{E}^{\mathbf{a}}_{\mathbf{tan}}$ is the aperture tangential electric field.

According to the method of moment theory**[3]**, the unknown currents (**J**) on the surface S of a radiating body are expressed in a finite modal expansion. This electric current density, induced on the BoR can now be decomposed into two orthogonal components along the unit vectors $\hat{t}$ and $\hat{\Phi}$ and expressed in the form**[4,5]**:

$$\overline{J}=\sum_{j} I_{j}\overline{J}_{j}$$

$$\overline{J}=\sum_{mj}\left(I^{t}_{mj}\overline{J}^{t}_{mj}+I^{\phi}_{mj}\overline{J}^{\phi}_{mj}\right) \qquad \textbf{.......... (2)}$$

Where J^{t}_{mj} , J^{φ}_{mj} are the tangential and circumferential components of an orthogonal set of expansion functions sparming the surface **S**, **m** is the index refer to the Fourier mode number includes all integers and zero, **j** is the subscript refers to the $\mathbf{j^{th}}$ annulus along the z-axis into which **S** is subsection, and I_j is the unknown coefficients of the expansion J_j .

The electric field can be expressed as :

$$E = -j\omega A(r)-\nabla\Phi(r) \qquad \textbf{.......... (3)}$$

where $\mathbf{A(r)}$ and $\Phi(r)$ represent the vector and scalar potential, respectively.

They are defined by :

$$\overline{A}=\mu\int_{s}\overline{J}\,\frac{e^{-jkR}}{4\pi R}\,ds \qquad \textbf{............ (4)}$$

$$\phi(r)=\frac{1}{\varepsilon}\int_{s}\sigma\,\frac{e^{-jkR}}{4\pi R}\,ds \qquad \text{..............} \ \textbf{(5)}$$

Where ε and μ are the permittivity and the permeability of the electric material, $\mathbf{R} = |\mathbf{r} - \acute{\mathbf{r}}|$, r and $\acute{r}$ are the position vectors of the field and source points, k is the wavenumber of free space, σ is the surface electric charge density, and $\bar{J}$ is the surface current density on **S** .

Combining eqs.{(1)-(5)} , we arrive at :

$$\hat{n}\times\bar{E}^{a}_{\tan}=\hat{n}\times\left[\,j\omega\mu\iint_{s}\bar{J}\,\frac{e^{-jkR}}{4\pi R}\,ds+\frac{\nabla}{j\omega\varepsilon}\iint_{s}\nabla'\cdot\bar{J}\,\frac{e^{-jkR}}{4\pi R}\,ds\right]_{\tan} \qquad \text{...............} \ \textbf{(6)}$$

Where :

$$\nabla\cdot\mathbf{J}=-\mathbf{j}\omega\sigma$$

As the procedure of the MoM, it will generally be advantage to choose weighting functions (**W**) that minimize the computations required to evaluate the inner products. Because of this, **W** is selected to be the complex conjugate of the surface current **(W = J*) [6]**.

By using the integro-differential operator L, Eq.(6) can be written as,

$$L\left(\sum_{j} I_{j}\bar{J}_{j}\right)=\bar{E}_{\tan}{}^{a} \qquad \text{................} \ \textbf{(7)}$$

The inner product of eq.(7) with **W** is :

$$\sum_{j} I_{j}\left\langle \bar{W}_{i},L(\bar{J}_{j})\right\rangle=\left\langle \bar{W}_{i},\bar{E}^{a}_{\tan}\right\rangle \qquad (i=1,2,3,\ldots) \qquad \text{................} \ \textbf{(8)}$$

Which can be written as :

$$[Z_{ij}]\ [\,I_{j}]=[\,V_{i}] \qquad \text{...............} \ \textbf{(9)}$$

Where :

$$[Z_{ij}]=\begin{bmatrix}\langle\bar{W}_{1},L(\bar{J}_{1})\rangle & \langle\bar{W}_{1},L(\bar{J}_{2})\rangle & \cdots & \langle\bar{W}_{1},L(\bar{J}_{j})\rangle\\ \langle\bar{W}_{2},L(\bar{J}_{1})\rangle & \langle\bar{W}_{2},L(\bar{J}_{2})\rangle & \cdots & \langle\bar{W}_{2},L(\bar{J}_{j})\rangle\\ \vdots & \vdots & \vdots & \vdots\\ \langle\bar{W}_{i},L(\bar{J}_{1})\rangle & \langle\bar{W}_{i},L(\bar{J}_{2})\rangle & \cdots & \langle\bar{W}_{i},L(\bar{J}_{j})\rangle\end{bmatrix} \qquad \text{...} \ \textbf{(10)}$$

is the generalized impedance matrix ,

$$[I_{j}]=\begin{bmatrix}I_{1}\\ I_{2}\\ \vdots\\ I_{j}\end{bmatrix} \qquad \text{...............} \textbf{(11)}$$

is the coefficients of current expansion to be determined, and

$$[V_{i}]=\begin{bmatrix}\langle\bar{W}_{1},\bar{E}^{a}_{\tan}\rangle\\ \langle\bar{W}_{2},\bar{E}^{a}_{\tan}\rangle\\ \vdots\\ \langle\bar{W}_{i},\bar{E}^{a}_{\tan}\rangle\end{bmatrix} \qquad \text{................} \ \textbf{(12)}$$

Is the excitation matrix includes the effects of antenna aperture.

Eq.(5) can be written as :

$$[\,I_{j}\,]=[\,Y_{ij}\,][\,V_{i}\,] \qquad \text{.........} \ \textbf{(13)}$$

Where $[\ Yij\ ]=[\ Zij\ ]^{-1}$ is the generalized admittance.

For BoR the impedance is obtained as**[6]** :

$$\left(Z_n^{tt}\right)_{ij} = \sum_{p=1}^{4}\sum_{q=1}^{4}\left[j\omega\mu T_p T_q \left(\sin(\upsilon_p)\sin(\upsilon_q)\frac{G_{n+1}+G_{n-1}}{2} + \cos(\upsilon_p)\cos(\upsilon_q) G_n \right) + \frac{1}{j\omega\varepsilon} T_p' T_q' G_n \right]$$

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

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

$$\left(Z_n^{\phi\phi}\right)_{ij} = \sum_{p=1}^{4}\sum_{q=1}^{4}\left[j\omega\mu T_p T_q \frac{G_{n+1}+G_{n-1}}{2} + \frac{n^2}{j\omega\varepsilon}\frac{T_p}{\rho_p}\frac{T_q}{\rho_q} G_n \right] \quad \textbf{....(14)}$$

Where G_n is the Green's function, n is the mode ,and the angle υ is the angle between the vectors $\hat{t}$ and $\hat{z}$.

And the excitation include the effects of antenna aperture can be obtained from eq.(12) , which yields to :

$$\begin{aligned} \left(V_0^{t\theta}\right)_i &= 2\pi \\ \left(V_0^{\phi\phi}\right)_i &= 2\pi \end{aligned} \quad \textbf{.......... (15)}$$

The total radiation field at any point in space , radiated in the θ and φ polarization by active apertures on a perfectly conducting body , can be expressed as :

$$\bar{E}\cdot\hat{u} = -\frac{j\omega\mu}{4\pi r} e^{-jkr}\left[R\right]\left[I\right] \quad \textbf{.... (16)}$$

Where $\hat{u}$ denotes θ or φ and [R] is the radiation transfer matrix or measurement matrix, which can be calculated as :

$$\left(R_n^{\alpha\theta}\right)_i = \iint_s \bar{J}_{ni}^{\alpha}\cdot\bar{E}_{\theta}^{r} ds \qquad \theta-polarized$$

$$\left(R_n^{\alpha\phi}\right)_i = \iint_s \bar{J}_{ni}^{\alpha}\cdot\bar{E}_{\phi}^{r} ds \qquad \phi-polarized \quad \textbf{... (17)}$$

Where

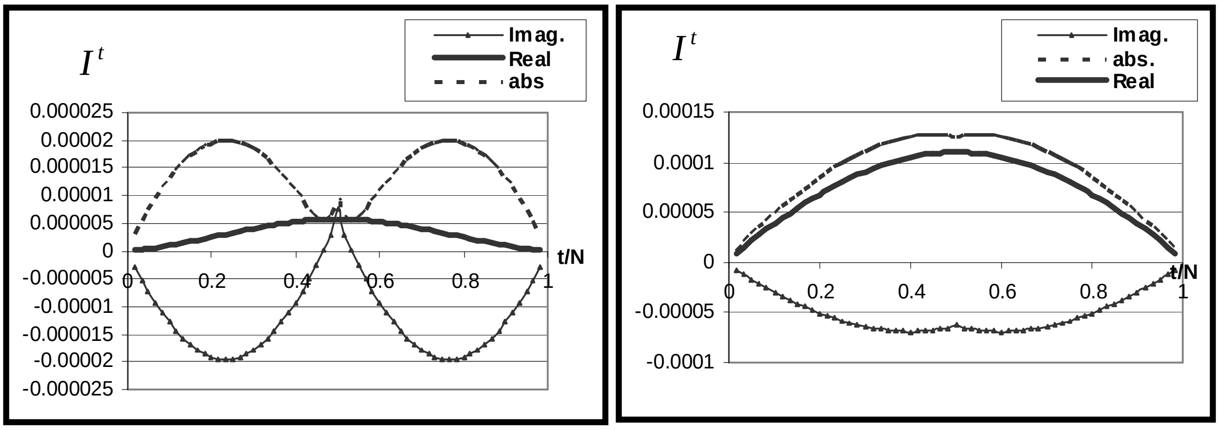
$$\bar{E}_{\theta}^{r} = \hat{u}_{\theta}^{r} e^{-jk_{\circ}\left[\rho\sin(\theta_r)\cos(\phi)+z\cos(\theta_r)\right]}$$

$$\bar{E}_{\phi}^{r} = \hat{u}_{\phi}^{r} e^{-jk_{\circ}\left[\rho\sin(\theta_r)\cos(\phi)+z\cos(\theta_r)\right]} \quad \textbf{... (18)}$$

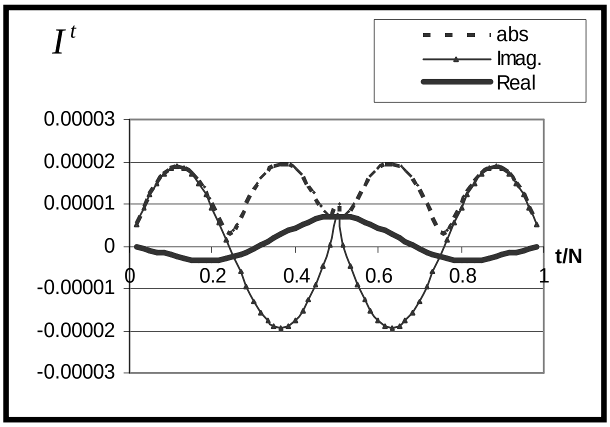
$\alpha \Rightarrow$ denotes t or ϕ.

RESULTS:

This work consists of two parts . The first part is considered with calculating the surface current of an perfect conducting cylinder after decreasing its radius to a very small value (a=0.001λ) to become like a wire, and the second part is considered with calculating the radiation fields of this wire.In practical, to understand the nature of the radiation from a BoR we must determine the surface currents on the outside boundary of this body (antenna). Fig.(2) shows the computed real , imaginary and the absolute value of the t-component of the coefficient electric surface current of this wire antenna for different electric length . The horizontal axis shows the normalized length of the antenna with respect to segment number.



$L/\lambda = 0.5$ $L/\lambda = 1$



$L/\lambda = 2$

Fig.2. Tangential component for the coefficients of surface current distribution for different lengths.

The radiation patterns in two orthogonal planes of a wire antenna of different length are plotted in Fig.(3).

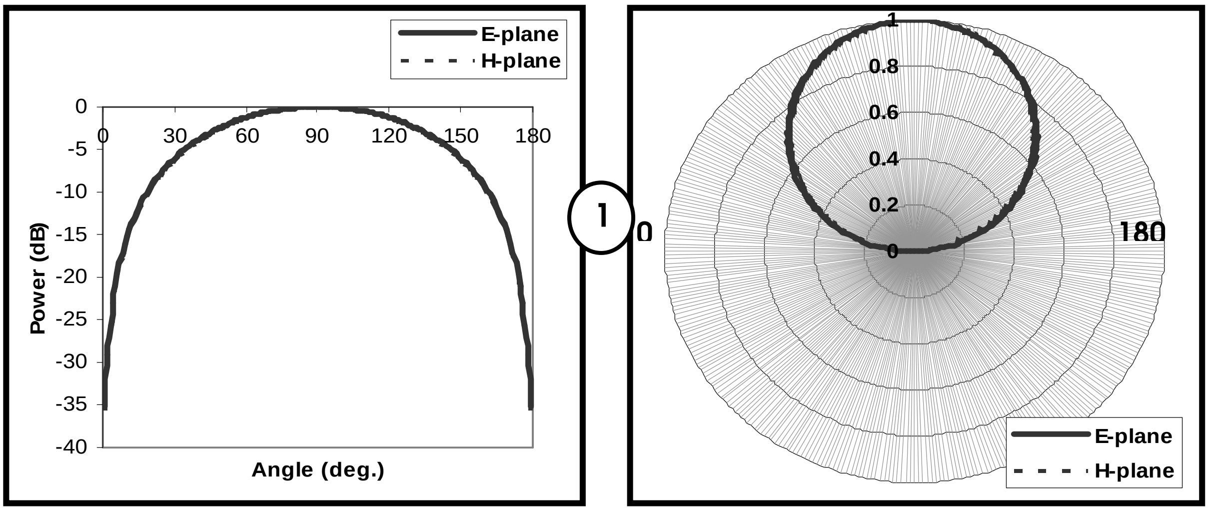
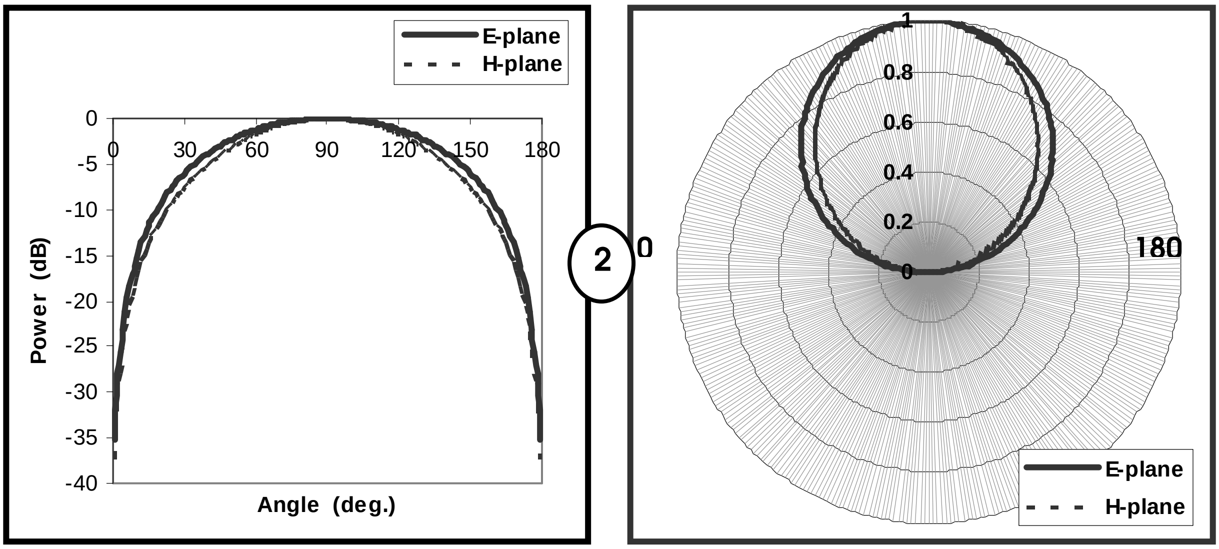
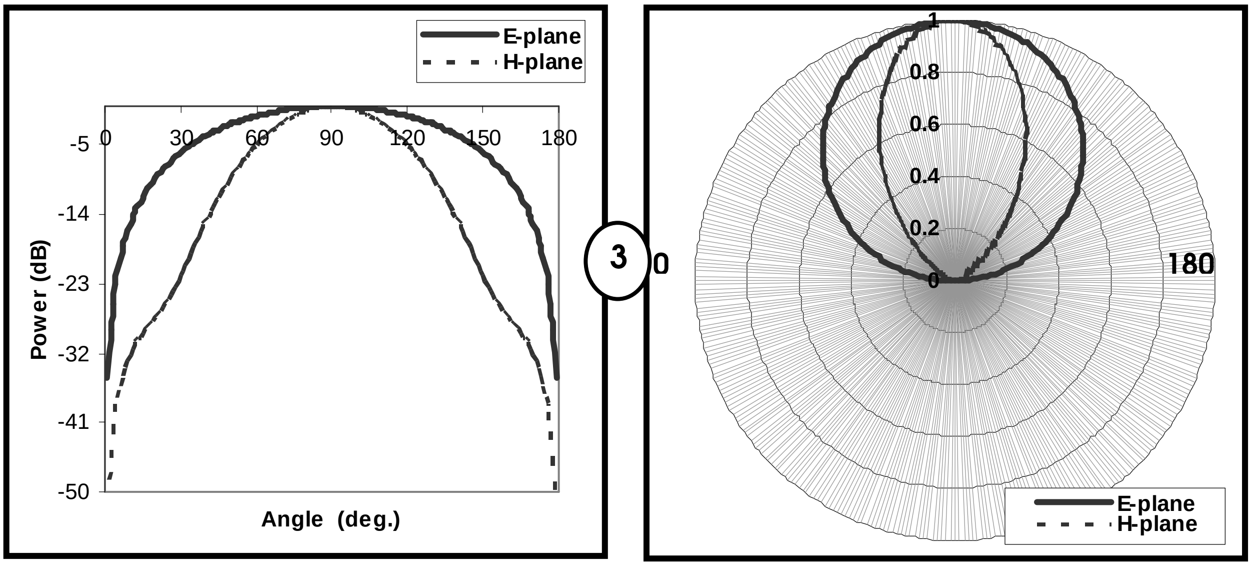


Fig.3. Radiation patterns for the wire antenna of different lengths:

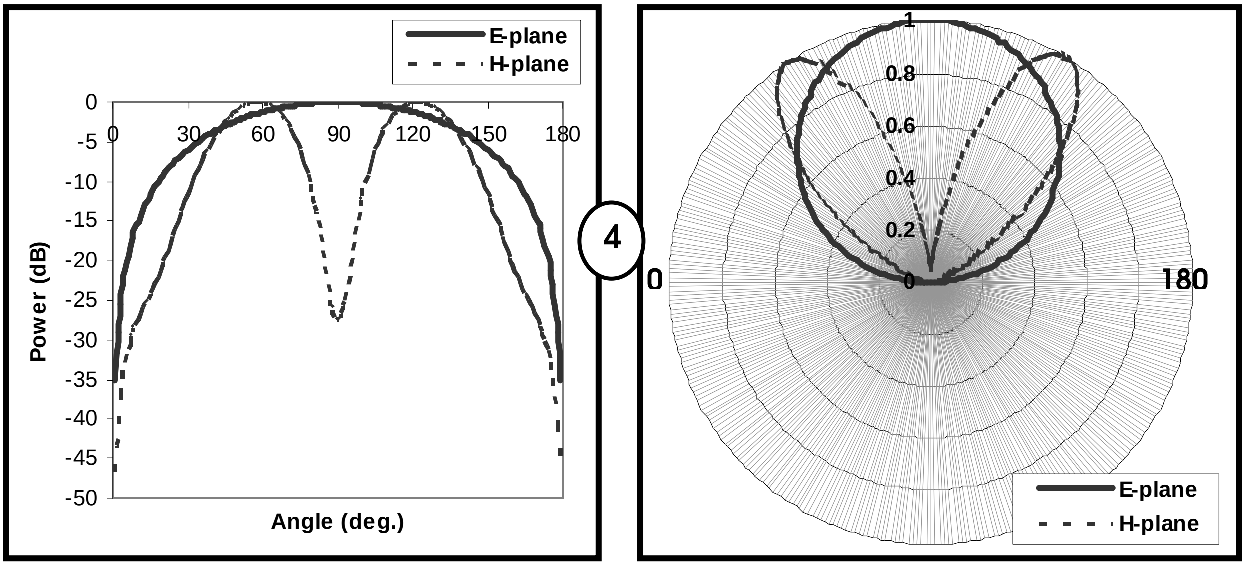
(1) 0.25λ **(2)** 0.5λ **(3)** 1λ **(4)** 2λ


E-plane
H-plane
0
-5
-10
-15
-20
-25
-30
-35
-40
0
30
60
90
120
150
180
Power (dB)
Angle (deg.)
1
0.8
0.6
0.4
0.2
0
0
180
E-plane
H-plane

2


E-plane
H-plane
-5
-14
-23
-32
-41
-50
0
30
60
90
120
150
180
Power (dB)
Angle (deg.)
1
0.8
0.6
0.4
0.2
0
0
180
E-plane
H-plane

3


E-plane
H-plane
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
30
60
90
120
150
180
Power (dB)
Angle (deg.)
1
0.8
0.6
0.4
0.2
0
0
180
E-plane
H-plane

4

It is shown from this figure that the peak of the radiation patterns are at θ equal $\frac{\pi}{2}$ for E-plane for all values of the length , while there are more than one peak as the length of the wire exceeds than one λ for H-plane. Fig.(4) shows a comparison between the radiation patterns of the wire antenna determined from eq.(16) for different electrical length and that determined from a well-known equation in the literature**[7]** ;

$$F(\theta) = \frac{\cos[(kL/2)\cos\theta] - \cos(kL/2)}{\sin\theta} \quad \textbf{... (19)}$$

This good agreement between these two results enable us to say that we introduce a new model for linear antenna (line source) parameters calculation which can be further modified in the future.

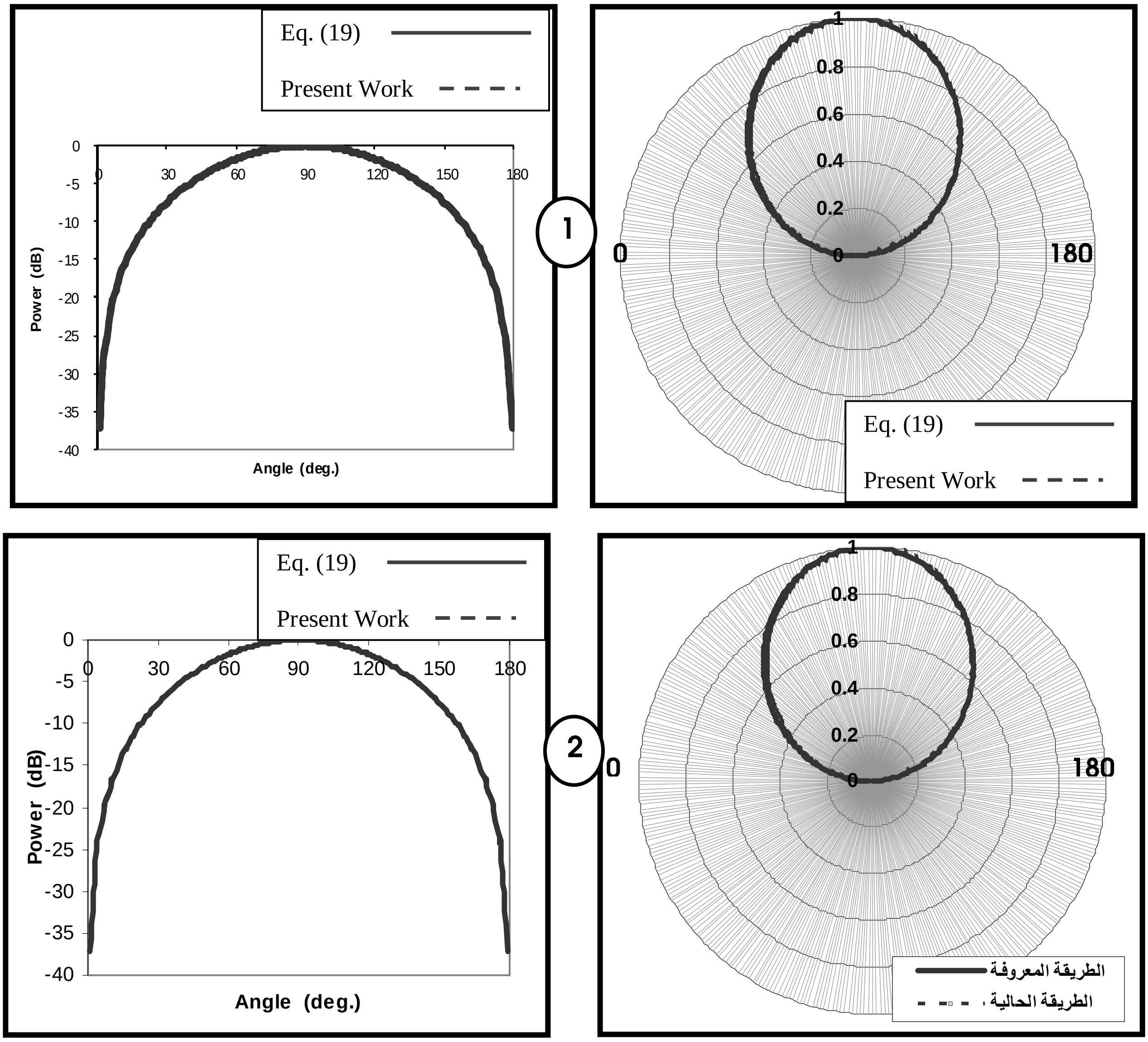
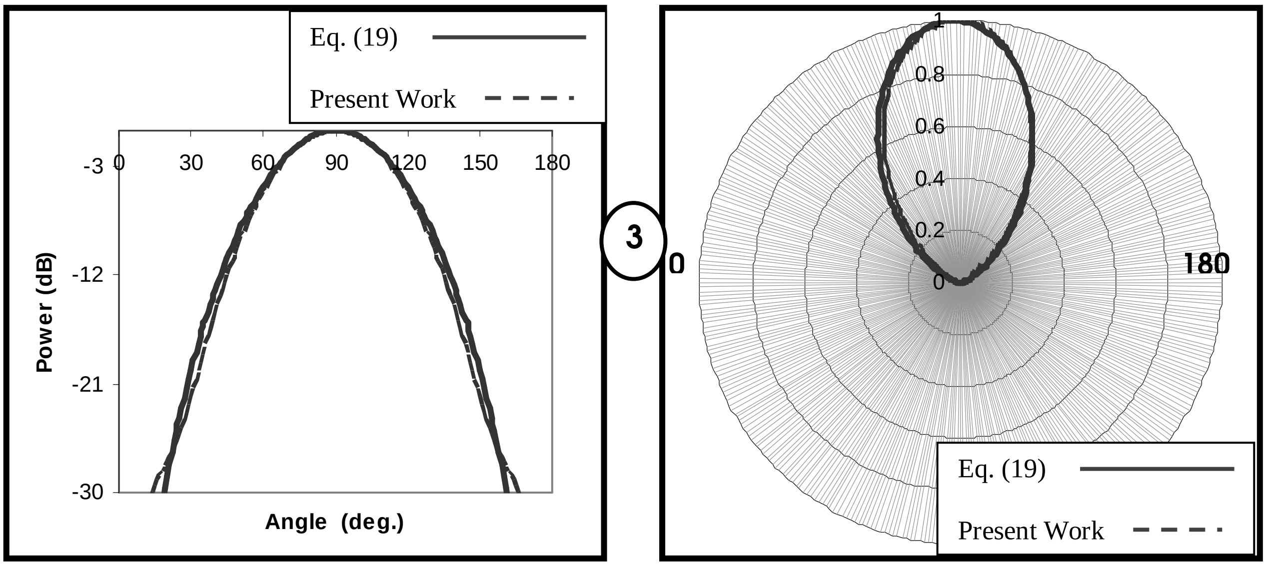


Fig.4. Comparison of radiation patterns (H-plane)of linear antenna of different lengths

(1) 0.25λ **(2)** 0.5λ **(3)** 1λ **(4)** 2λ



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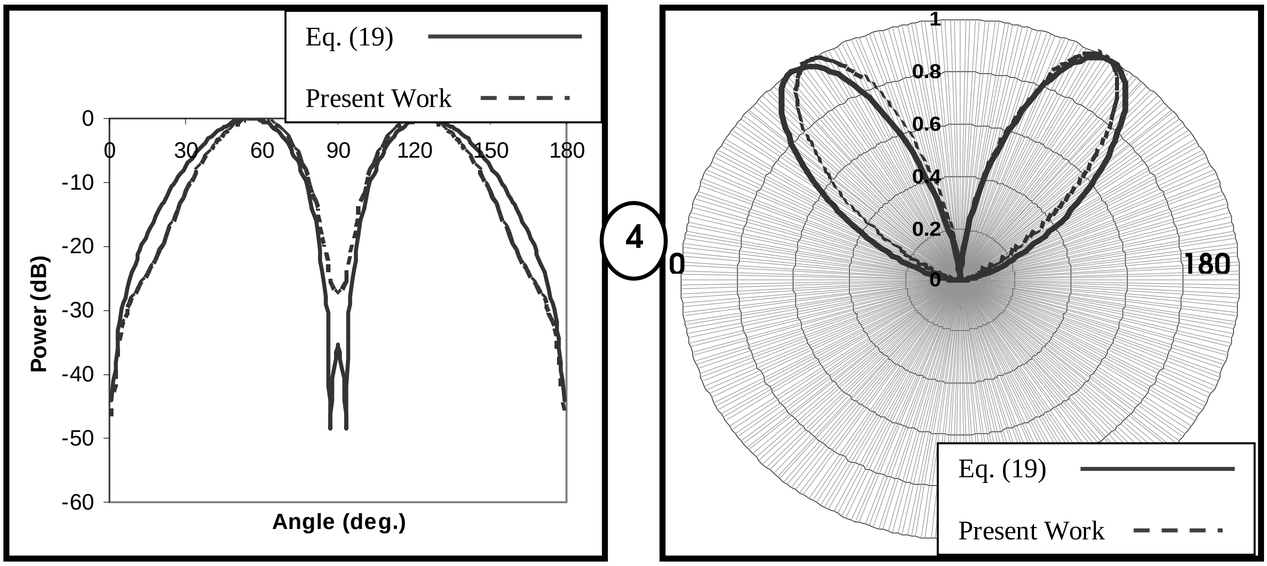

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CONCLUSION:

In this theoretical study, the aperture antenna was made as an approach to linear antenna through decreasing the radius of conducting cylinder (BoR) to very small value so that it will be like a wire.

The numerical results show a very good agreement with the previously published data determined by a well-known theory and with other numerical methods. Future work should concentrate on developing this model to find other parameters of this wire antenna.

REFFERENCES:

[1] A. K. Abdelmageed ," ***Efficient evaluation of modal Green's functions arising in EM scattering by bodies of revolution***.", Progress in Electromagnetics Research , PIER 27, pp. 337-356 ,2000 .

[2] V. R. Pereyra , A. Z. Elsherbeni , and C. E. Smith ," ***A body of revolution finite difference time domain method perfectly matched layer absorbing boundry*** ", Progress in Electromagnetics Research , PIER 24, pp. 257-277 ,1999 .

[3] L. N. Medgyesi-Mitschang , and J. H. Mullen ," ***Radiation and scattering from asymmetrically excited bodies of revolution***", IEEE Transaction Antenna and Propagation ., pp. 90-93 , 1976

[4] K. A. Iskander , L. Shafai , A. Frandsen , and J. E. Hansen ," ***Application of impedance boundary conditions to numerical solution of corrugated circular horen*** ", IEEE Transaction Antenna and Propagation ., Vol. AP-30 , No;3, pp. 366-372 , 1982.

[5] P. L. Huddleston , L. N. Medgyesi-Mitschang , and J. M. Putnam ," ***Combined field integral equation formulation for scattering by dielectrically coated conducting bodies***", IEEE Transaction Antenna and Propagation ., Vol. AP-34 , No;4, pp. 510-520 , 1986.

[6] J. R. Mautz , and R. F. Harrington ," ***Radiation and Scattering from Bodies of Revolution*** " , Appl. Sci. Res., Vol. 20, pp. 405-435, 1969.

[7] C. E. Jordon ," ***Electromagnetic Wave and Radiation Systems*** ", Prentice-Hall of India Fimited New Odhi,1974.

دراسة نظرية في حساب مجالات الإشعاع الصادرة عن هوائي خطي كجسم متناظر محوريا (BoR)

رانيا مسلم داود[1]   احمد هاشم عبود[2]   زكي عبد الله احمد[1]

[1]قسم الفيزياء – كلية العلوم – جامعة البصرة

[2]كلية التربية الأساس – جامعة ميسان

الخلاصة:-

أن معالجة مسالة الإشعاع الكهرومغناطيسي في هذه الدراسة قد اعتمدت على الأجسام الموصلة كهربائياً المتناظرة محوريا والتي تسهل علينا المعالجة المبنية على أساس التعامل مع المعادلة التكاملية للمجال الكهربائي فقط والتي تم اعتماد طريقة العزوم العددية مع تقنية كالركن في حلها حيث أعطتنا نتائج غاية في الدقة. يقدم هذا البحث دراسة نظرية لوصف دالة التيارات السطحية وحساب المجالات الإشعاعية المنبعثة من هوائي سلكي، حيث تم في هذه الدراسة تقريب هوائي الفتحة إلى هوائي سلكي(خطي) من خلال تقليل نصف القطر إلى مقدار صغير جدا بحيث تصبح الاسطوانة عبارة عن سلك. أن اعتماد هذه الفرضية أدت إلى نتائج متطابقة إلى حد كبير جداً مع النتائج الخاصة بالمصدر الخطي المعروف بصورة أساسية في أدبيات الموضوع وهذا ما مكننا من القول أن هذه الطريقة التي اعتُمدت في بحثنا تُعتبر نموذجاً جديداً في حساب معاملات الهوائي السلكي والتي يمكن تطويرها في المستقبل لإيجاد بقية المعاملات وخصوصاً مقاومة الإشعاع.