RADIATION PATTERN OF A UNIFORM LINEAR ARRAY OF WIRE ANTENNAS

* Ifeoma B. Asianuba **Anthony N. Nzeako PhD
* University of Port Harcourt,
Department of Electronic/ Computer Engineering, Rivers State, Nigeria.
**University of Nigeria, Nsukka.

ABSTRACT: Wireless communication process which include; point-to-point, broadcast, satellite communication etc. are prone to fading, interference and attenuation due to very long distances involved in the communication process. In other words, highly directional antennas are required to meet these challenges for efficient communication process. In this work the relationship between a uniform linear array antenna and its equivalent radiation pattern is presented. An efficient technique based on the Method of Moments (MoM) formulation is used in the analysis of the wire antenna. The Hallen's differential equation describes the analysis using piecewise constant function for determining the current distribution of the antenna. Applying the pattern multiplication principle, the radiation pattern of the array is achieved showing the impact of the inter-element spacing and number of array element on the overall radiation pattern

Index Terms: Wire Antennas, Moment Method, Array factor, Radiation pattern

◆

I. Introduction

Antennas are fundamental areas of any wireless communication system. It is used because of the inability to lay a physical connection between a transmitting and receiving device due to long distances involved. The latter is associated with some difficulties viz-a-viz fading, interference, attenuation etc. For this reason highly directional antennas are desirable to achieve effective communication process. In point-to-point, broadcast, directional and space communication. It is imperative to note that the number of antenna elements, its material constituents and the geometry of the structure affects the required beam pattern that can be generated. However, antennas with a known radiation pattern can be arranged in such a way that they can either enforce/destroy the generated signal depending on the design interest.

The wire antenna is one of the most versatile antennas [1] that find application in diverse communication process, but as a single element it is insufficient to meet effective requirement of narrow beam, reduced side lobes, good efficiency and directivity. Due to these limited technical needs, it is subject to limited performance. A collection of discrete wire antenna elements to constitute an array offers solution to direct radiated power towards

IJSER

a desired angular sector so that with proper choice of array feed model and geometry, any desired pattern can be modeled. There are principally five parameters that can model the radiation pattern of array antenna. These include the geometrical configuration (which may include linear, circular, planar and conformal arrays), relative displacement between elements, excitation amplitude of the respective antennas, excitation phase of the individual elements and relative pattern of the individual elements [2, 3].

Basically there are two principal approaches to the modeling of array antenna with elements either coupled or parasitic. The first involves that of array synthesis where a desired radiation pattern is given and a choice of the appropriate array is expected. It also involves the determination of the feed condition of the resulting configuration [4]. The second approach which is adopted in this work specifies the geometry of the array and its associated feed model. It requires adopting numerical techniques to obtain the parameter of engineering interest (Beam pattern) associated with the array. Numerical technique has been a very important approach in engineering and especially antenna analysis due to the fast growing trends of digital computers. They include MoM, FEM, FDTD etc. The most popular and appropriate for linear antenna analysis is the MoM. It was formulated by Harrington [5] and ever since has been applied by many researchers. There are conventional electromagnetic softwares that have been used in analysis and synthesis of wire antennas. The first codes were generated at Lawrence Liver Moore laboratories for analysis of wire antennas but were written in Fortran [6]. Subsequent codes include NEC 4, Mini NEC etc. Most of which were analyzed with collocation method.

IJSER

In this work is carried out the analysis of arrays of wire antenna using point matching formulation to determine the current distribution of a single element antenna. With this parameter the radiation pattern of the array can be obtained applying the principle of pattern multiplication. The outcome will show the relationship between geometrical arrangement of the antenna and the beam pattern. The entire work were all simulated with matlab

II. Formulation

Consider a uniform, non staggered equal length equal spaced, center fed array of wire antennas oriented along the z-axis of a co-ordinate system. The currents distribution is along the axis of the elements and is determined by Moment Method. The formulation involves Hallen's equation with piecewise constant approach using the approximate Kernel. Another kernel approach also exists. This is known as the exact kernel. It finds more application in wires of large diameters. In that case the filamentary current flows across the radius of the wire. The use of the exact kernel also results in well-defined solutions [7]

Basically two domain function can be used in the problem of antenna analysis, the entire domain function which usually exists over the entire surface of the unknown and requires no segmentation. The second is the sub domain basis function and is defined over the specified segments. Applying the boundary condition at the surface of the perfectly conducting wire, the sum of the scattered and incident fields vanishes thus:

$E^i = -E^s$

The electric field (E^s) outside the conductor is derivable entirely from the vector potential A i.e.

$$E^s = -Jw\varepsilon\nabla\ (\nabla.A) - JwA \qquad (1)$$

Therefore

$$\int_{-l'2}^{l/2} I(z')G(z,z')dz' = -E^i(z) \qquad (2)$$

If the current is approximated by a pulse expansion function so that

$$I(z') = \sum_{n=1}^{N} I_n F_n$$

Where $F_n(z) = \begin{cases} 1 & \text{for z' in } \Delta\text{zn} \\ \text{o} & \text{elsewhere} \end{cases}$

$$\sum_{n=1}^{N} In \int_{=l/2}^{l'2} G(zm\quad z') = -E(z) \qquad (3)$$

In order to obtain a balanced set of equation on both sides of the expression, the source is reacted upon by a derac delta weighting function given by $w(z) = \delta(z - zm)$

So that

$$\sum_{n=1}^{N} s \int_{zn-\frac{\Delta z}{2}}^{zn+\frac{\Delta z}{2}} G(zm,z') = \frac{-j}{\eta}\ (A\cos(kz) + \frac{VT}{2} Sin\ (k/z/\ ] \qquad (4)$$

Where $G\,(zm,\ z')$ = Green's function and is given by

$$\frac{e^{jkR}}{4\pi R}$$

$m = 1, 2........N$

IJSER

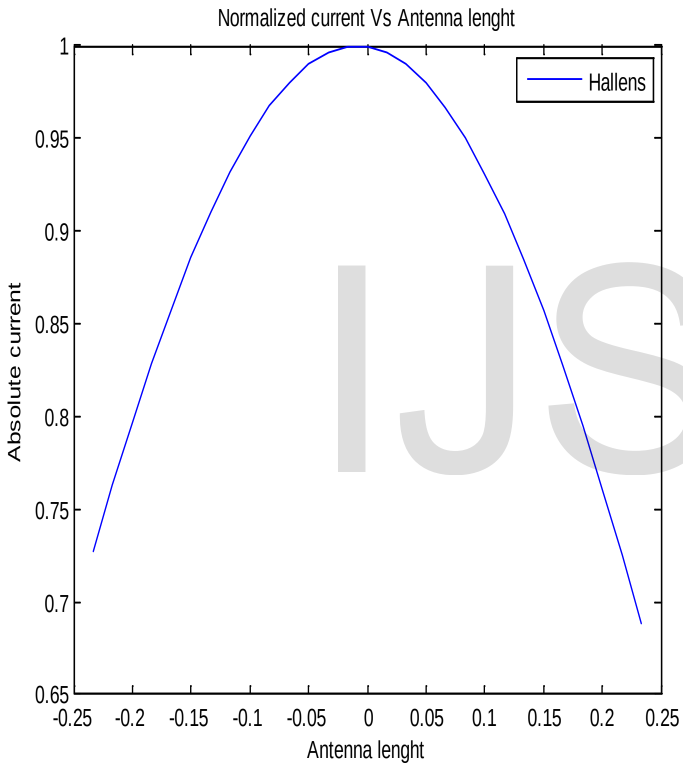
R = $\sqrt{a^2 + (z - z')^2}$

a = radius of the wire

Equation 4 can be represented by a network equation given by

$$Z_{mn}\ I_n = V_m$$

The current distribution is used to determine the radiation field of the wire antenna by the expression



IJSER

Fig. 1 Current Distribution on a wire antenna

$$E_\theta = \frac{jwu}{4\pi R}\, e^{-jkR} \int I\, d\ell \qquad (5)$$

Array pattern = Array element pattern x Array factor (AF)

The array factor is a function that is dependent only on the geometry and the excitation of the antenna. It is independent of the antenna type when all elements are identical. Considering a uniformly spaced wire element with a linearly progressive phase from element to element

$$I_1 = I_o \quad I_2 = Io\, e^{j\phi 2} \quad I_3 = Io\, e^{j\phi 3}$$

ϕ = phase shift

The overall array far field is obtained by using the superposition principle

$$E_\theta = E_{\theta 1} + E_{\theta 2} + E_{\theta 3} + \ldots\ldots E_{\theta N}$$

$$E_\theta = E_\theta\, [AF]$$

The array factor is given by

$$AF = \frac{Sin\left(\frac{N\psi}{2}\right)}{Sin\left(\frac{\psi}{2}\right)} \qquad (6)$$

Where ψ = phase function = kdcosθ

d = inter element spacing

k = wave number

θ = elevation angle

The phase function ψ is a function of the element spacing, phase shift, frequency and elevation angle.

The array factor may be normalized so that the maximum value for any value of N is unity. The normalized array factor is given as

$$AF_n = \frac{1}{N}\,\frac{Sin\left(\frac{N\psi}{2}\right)}{Sin\left(\frac{\psi}{2}\right)} \qquad (7)$$

III. Results and Discussions

The normalized radiation pattern for the single wire antenna is shown in fig 2. Various plot of the array factor is also shown. It is observed that; the un-normalized array factor maximum occurs at phase = 0 and is equal to the number of the antenna elements in the array. The total number of lobes in the plot is equal to the number of antennas N. It is also observed that there are N – 2 side lobes for every N element considered.. The main lobe width can be determined from $\frac{4\pi}{N}$ and the minor lobe width = $\frac{2\pi}{N}$.

IJSER

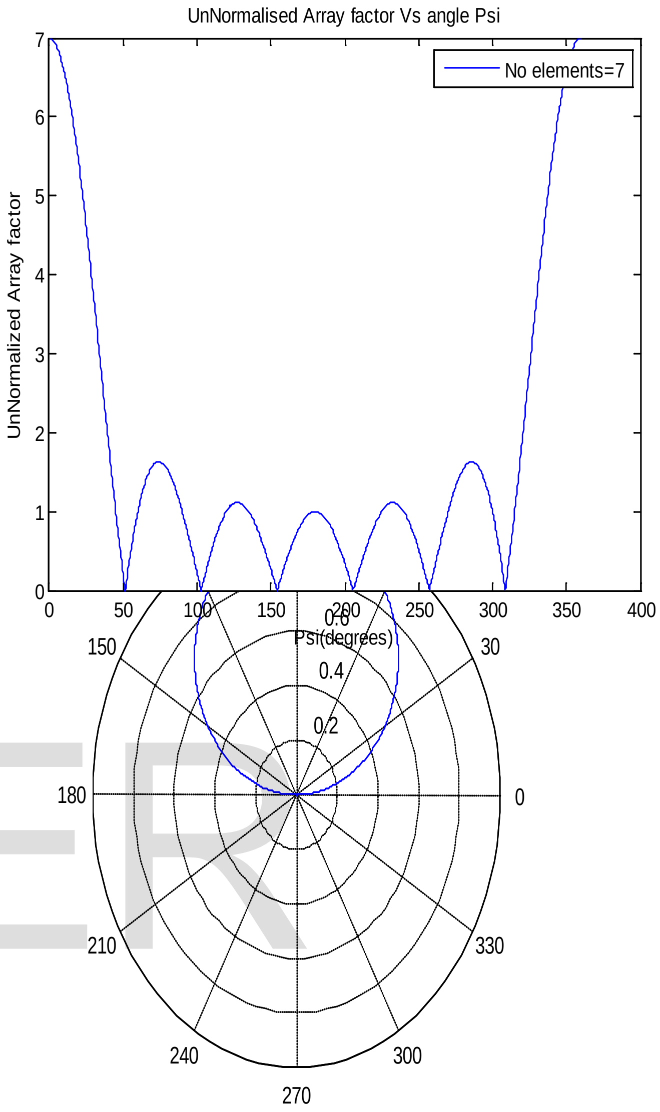


Fig. 2: Radiation pattern of a wire antenna

For the normalized array factor, the nulls of the array function are obtained by determining the zeros of the numerator term where the denominator is not simultaneously zero. That is

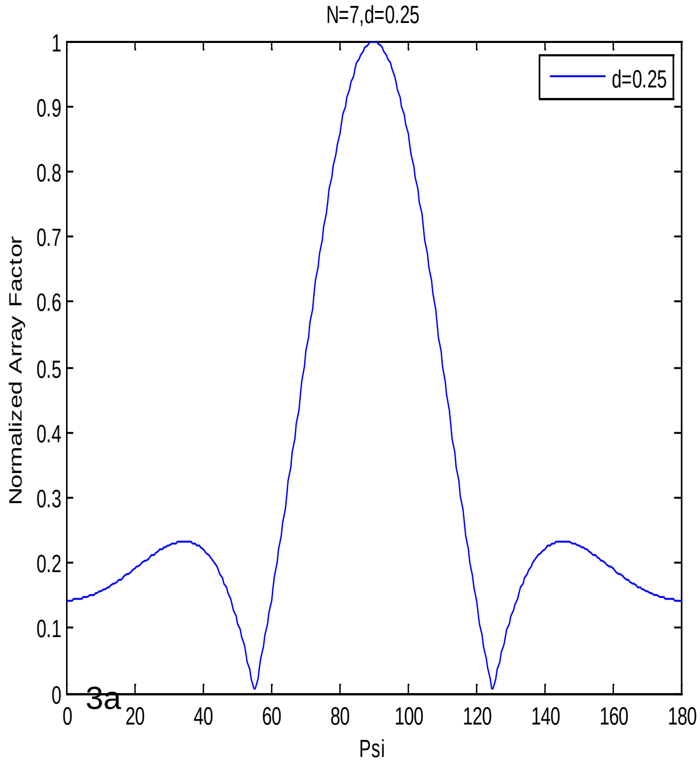
$$Sin\left(\frac{N\psi}{2}\right) = 0$$

The peaks of the array function are found by determining the zeros of the numerator term where the denominator is simultaneously zero.

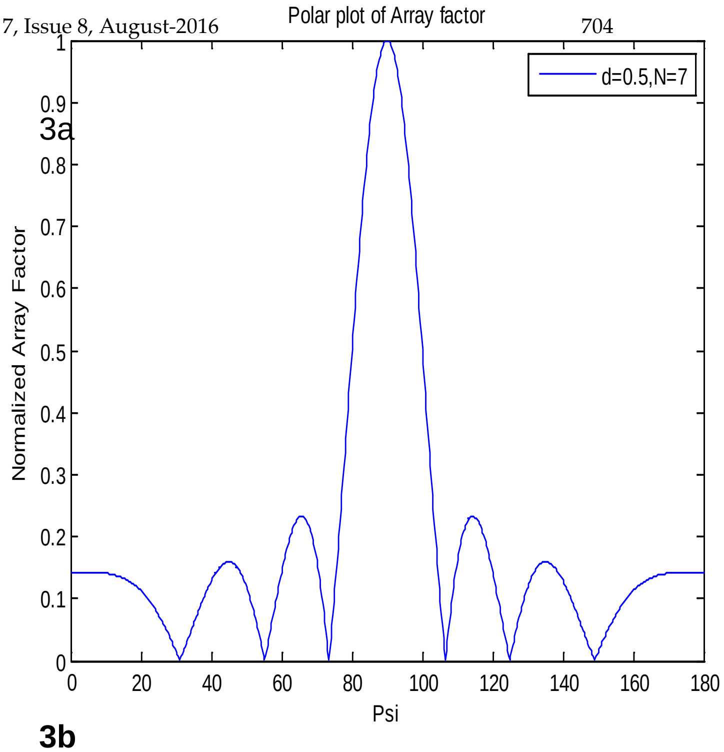
$$\theta_m = \cos^{-1}\left[\frac{\lambda}{2\pi d}(-\alpha + 2m\pi)\right] m = 0,\ 1,\ 2$$

The phasing of the uniform linear array elements may be chosen such that the main lobe of the array lies along the array axis so that the phase shift is zero.

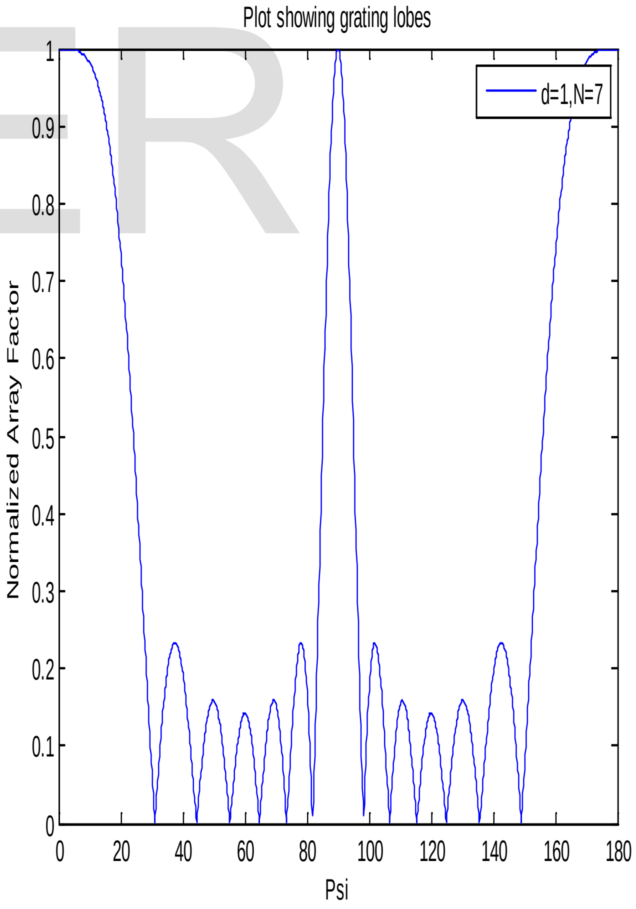
IJSER



3a



3b



3c

Fig. 3 Array factor plot for different inter-element spacing

(a) d = 0.25λ

(b) d = 0.5λ

(c) d = 1λ

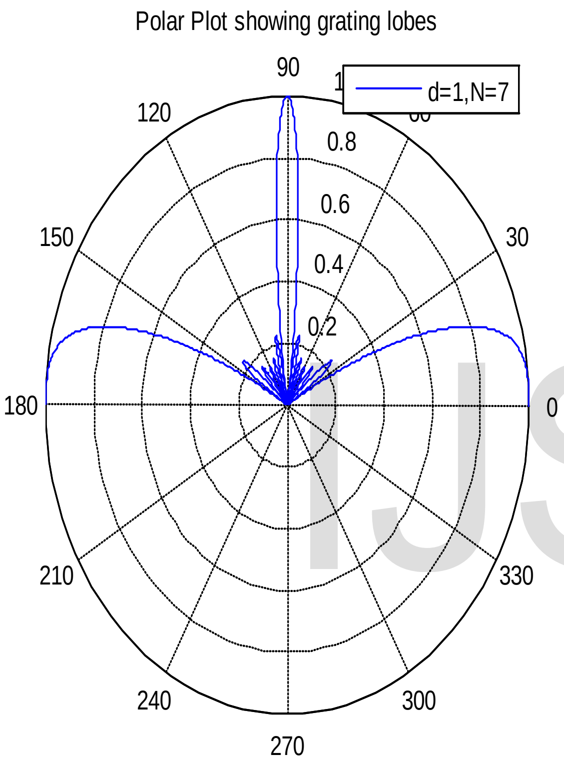
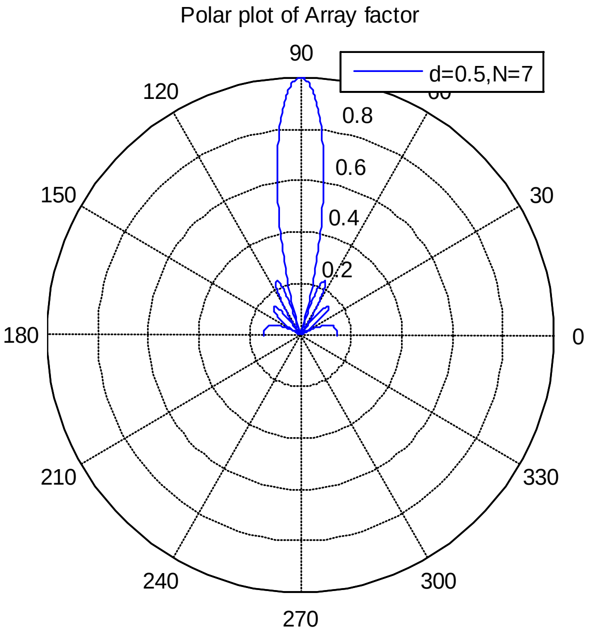


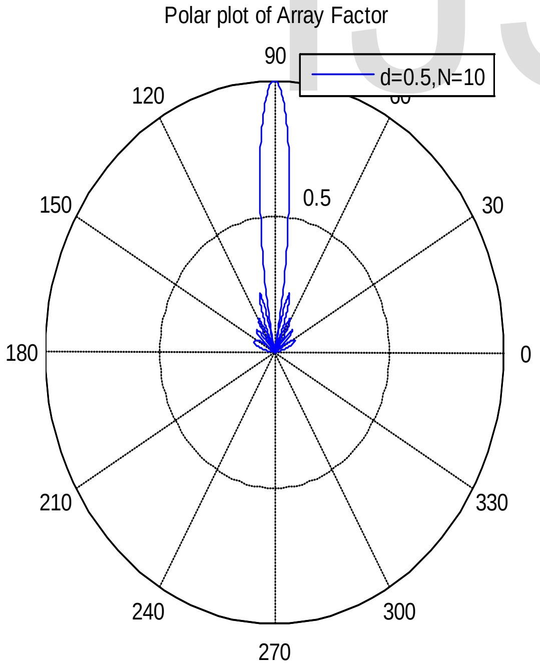
Fig. 4 Radiation pattern showing grating lobes

It is interesting to note the impact of the element spacing on the radiation pattern of the uniform array. With a zero phase difference (α = 0), as the element spacing is increased, the main lobe beam width is decreased. The signal becomes highly directional with good directivity. Array of wire antenna is essential for point-to-point communication in other to achieve good directivity. The directivity of the antenna array is increased with increased element spacing. However grating lobes (radiations in directions other than the main direction of interest) are introduced when the element spacing is greater than or equal to one wave length. Grating lobes have destructive effects on the desired radiation pattern and can cause misinterpretation of signal, interferences, hazardous effects on humans at work station etc. For an array design that requires no grating lobes, the element spacing should be chosen to be less than one wave length. It is also observed that as the number of array elements increases, the main beam is sharpened. Fig. (5) but increased side lobes is seen. Although the side lobes are reduced in size.

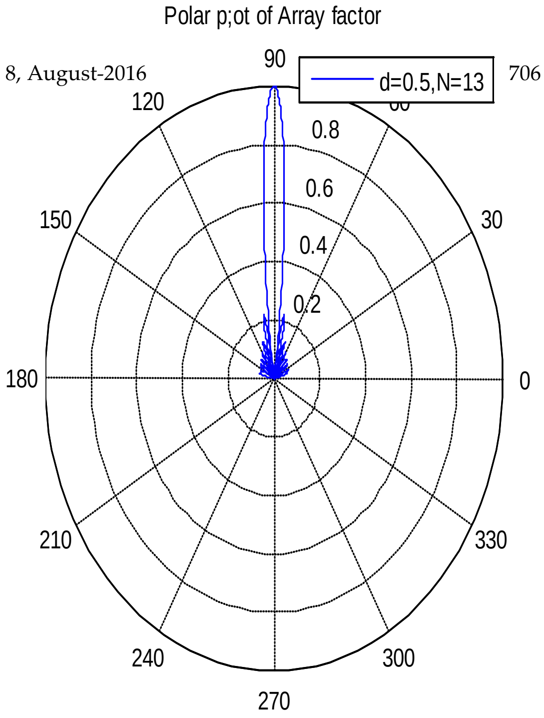
IJSER



5a



5b



5c

Fig. 5 Radiation pattern for various number of elements

(a) N = 7

(b) N = 10

(c) N = 13

IJSER

IV. Conclusion

In this work very reliable approach has be used to determine the current necessary for radiation of electromagnetic waves from an antenna. This parameter is used to obtain the radiation pattern of the wire. Applying the superposition principle the array factor is obtained. The pattern multiplication approach enables the radiation pattern of the entire array to be generated for the desired communication process. The entire process has shown the relationship between the array radiation pattern with respect to the uniform inter element spacing .It is also seen in this work that as the number of antenna element increases ,the directivity of the radiation pattern increases with the presence of a reduced beam width , thus an enhanced communication process.

V. References

[1] G. Fikiroirs, S. Lygkouris and P.J. Papakanellos. Method of Memonet Analysis of Resonant Circular arrays of cylindrical Dipoles IEEE trans on ANT & Prop vol.59 No.12December 2011

[2] C.A. Balanis “Antenna theory analysis and design” 2nd edition John Wiley and Sons Inc. New York 1997

[3] R.L. Haupt and D.H. Werner, Genetic Algorithm in electromagnetics IEEE press Wiley Interscience 2007

[4] B.D. Popovic simple methods of analyzing array of thin cylindrical dipoles proc IEEE vol. 117 No 6. June 1970.

[5] R.F. Harington. Field computation by Moment Methods

[6] G.J. Burke, A.J. Poggw Numerial Electromagnetic code (NEC Method of Moment programme description January 1981

[7] R.W.P. King, J. Fikioris and R.B. Mack “Cylindrical antennas and arrays Cambridge University Press 2002.

IJSER