ArrayAnt V1.0
Radiation Pattern Analysis of Linear Antenna Arrays

Introduction

Antennas with good directive characteristics can be achieved without necessarily increasing the size of an antenna element instead by forming an assembly of radiating elements in electrical and geometrical configurations. Such structures are called Antenna Arrays. The radiation characteristics of such structures are governed by

1. the geometrical configuration (Linear, Circular, Rectangular, Spherical etc.,)
2. the relative displacement between the elements
3. the excitation amplitude of the individual elements
4. the excitation phase of the individual elements
5. the relative pattern of the individual elements

The software presented below can deal with Linear arrays with either Uniform, Bionomial or Dolph-Chebyscheff Distribution of the excitation amplitude of the individual elements. The phase of the individual elements can be controlled as desired by the user. The software can analyze Uniform BroadSide, Endfire, Phased (Scanning) arrays and Hansen Woodyard (improved endfire array). Generally in practice, Binomial and Dolph-Chebyscheff arrays designs are BroadSide.

The individual array elements can be modeled in the software are

1. Isotropic radiators(point source)
2. Short dipoles (physical length < 0.1λ)
3. Dipole Antennas

The software computes the radiation characteristics by the method of Multiplication of Patterns. By this method the Total radiation pattern of an Antenna Array is the product of the individual array element's radiation pattern in the desired plane and the Array Factor. The Array Factor is the characteistic of the array geometry and does not depend on the individual array element. This version of the software can compute the radiation pattern in the vertical plane only with the linear array elements stacked along the z-axis. Dipole elements are modeled to be oriented along the z-axis.

Numerical Analysis

The numerical analysis involved in modeling the array and the elements is listed below. The equations have been optimized significantly in order to reduce the execution time.

Array Factor

As said earlier, Array Factor is the characteristic of each array geometry. It doesnot depend on the array element type but depends on parameters like current amplitude in each element of the array, distance or spacing between the array elements. Once Array Factor is computed by the following formulae, the total radiation pattern of the entire array antenna is obtained by multiplying the Array factor with the individual Element pattern. As said earlier the three different amplitude excitation technique dealt are

1. **Uniform Amplitude** – all the elements have equal current amplitude fed to them
2. **Binomial Distribution** – the elements have different amplitudes whose ratio forms a binomial distribution. Here directivity of the array is very much increased.

   Eg:

5 elements	a3	a2	a1	a2	a3
5 Amp ratio	1	4	6	4	1

It is seen that as number of elements increase the amplitude of the center element is significantly higher than end element's amplitude. To avoid such a wide variation in current amplitude one can go for Dolph-Chebycheff array

3. **Dolph Chebycheff distribution** – the elements have non-uniform amplitude distribution. The advantage of this over binomial is that the current amplitude variation between different elements is significantly low. The ratio of Main lobe to Side lobe power can be fixed as desired by the user. The R0 variable takes care of this. If the user while specifying the parameters enters R0 as 20 dB then the generated Array pattern would have a difference between the Main lobe and Side lobe as 20dB. Thus highly directive arrays can be analyzed.

AF = $\sin(N*\psi/2)/\sin(\psi/2)$ for Uniform Amplitude

= $\sum_{n=1}^{M} a_n \cos[(2n-1)\,\psi/2]$ for Non Uniform Amplitude with even number of elements

= $\sum_{n=1}^{M+1} a_n \cos[2(n-1)\,\psi/2]$ for Non Uniform Amplitude with odd number of elements

where N = 2M is even number of array elements

= 2M+1 is odd number of array elements

$\psi = \beta d \cos(\theta) + \alpha$

$\beta = 2\Pi/\lambda$

d = distance between array elements in wavelength

α = Progressive phase shift in the excitation current in each element

a_n = excitation amplitude of element n

For Uniform Amplitude

a_n = 1 for all n

For Binomial Distribution

$$a_n = \frac{(N-1)!}{(M-n)!(N-M-1+n)!}$$ for even 2M elements, n=1,2,…M

$$a_n = \frac{(N-1)!}{e_n\,(M+1-n)!(N-M-2+n)!}$$ for odd 2M+1 elements, n=1,2,3…M+1

e_n = 2 ; n=1

= 1; otherwise

For Dolph-Chebyscheff distribution

R_0= Voltage ratio = $10^{R0(dB)/20}$ (as desired by the User)

Defining variable P as P = N-1

Defining a variable Z0 as $Z_0 = 0.5[\,(R_0 + \sqrt{(R_0^2 - 1)})^{1/P} + (R_0 - \sqrt{(R_0^2 - 1)})^{1/P}]$

$$a_n = \sum_{q=n}^{M} (-1)^{M-q} (Z_0)^{2q-1} \frac{(q+M-2)!(2M-1)}{(q-n)!(q+n-1)!(M-q)!} \quad \text{for even 2M elements, } n=1,2,\ldots M$$

$$a_n = \sum_{q=n}^{M+1} (-1)^{M-q+1} (Z_0)^{2(q-1)} \frac{(q+M-2)!(2M)}{e_n (q-n)!(q+n-2)!(M-q+1)!} \quad \text{for odd 2M+1 elements}$$

$n=1,2,3\ldots M+1$

$e_n = 2$; $n=1$

$= 1$; otherwise

Element Pattern

The element pattern is the radiation pattern of each of the individual array elements.They are given as

Isotropic Radiator

Normalized $E(\theta) = 1$

This implies that the Array Factor and the Total array pattern are the same for an antenna array made of Isotropic radiators as the individual array elements.

Short Dipole

Normalized $E(\theta) = |\cos(\theta)|$

This results in a figure of 8 pattern and modifies the Array Factor accordingly to give a resultant Total array pattern.

Dipole of length L

$$E(\theta) = \frac{|\cos(0.5\ \beta L \cos(\theta)) - \cos(0.5\ \beta L)|}{|\mathrm{Sin}(\theta)|}$$

This implies that the element pattern depends on the length of the dipole. Hence the required total radiation pattern can be achieved by playing on the length of the dipole for a give array geometry (i.e., Array factor).

Note: All angles (θ,ψ) are in radians.

Software

The software is mouse based and need a mouse to access the pull down menu. However short cut keys have been provided for each function in the menu.

'n' – New Array
'o' – Open
's' – Save
'p' – Patterns
'a' – Array Factor
'e' – Elemnet Pattern
't' – Total pattern
'v' – View antenna
'h' – About
'x' – Exit

Functions

New Array

To create new antenna array geometry. A sequence of data is to entered by the user according to his design. The 'Adat.inf' file is necessary for the execution of the program and it contains the sequence of questions necessary for the array analysis. The number of elements is to be not more than 20.

Open

To open already saved array designs. The software can save the modeled antenna arrays in a particular format. These files can be opened and analyzed whenever required. The files must have a .ant extension.

Save

To save the array specifications in the hard disk. The files must have a .ant extension. These files can later be accessed and analyzed.

Patterns

Once a new array data is specified or a saved data is retrieved, this option in the menu is to be accessed. The Array Factor, Element Pattern and the total pattern are computed and are stored in temporary files, 'temp0.dat', 'temp1.dat' and 'temp2.dat' respectively. The polar plots of these patterns are drawn in the screen

Array Factor, Element Pattern, Total Pattern

To zoom the computed array factor, element pattern or the total pattern respectively. The pattern can be scanned for an increment in the elevation angle of 1°. For each value of the elevation angle the field amplitude in dB and the elevation angle in degrees are displayed. Esc key has to be pressed to return to the normal screen.

View Antenna

To display the antenna array geometry with the current amplitudes of all the elements. Esc key has to be pressed to return to the normal screen.

About

To display details about the software ArrayAnt V1.0. Enter key has to be pressed to return to the normal screen.

Exit

To exit the program and return to DOS.

Note: The file cmouse.h containing the mouse interface functions was already published in one of my previous articles, Smith Chart Simulator – Aug 1999 issue of EFY.

Sequence of Data input

1. Type of amplitude distribution
   - Uniform
   - Binomial
   - Dolph-Chebyscheff
     - Major to Minor lobe ratio

2. Type of array element
   - Isotropic
   - Short Dipole
   - Dipole Antenna
     - Length of dipole

3. Type of antenna array
   - Broad Side
   - Endfire
   - Phased (Scanning)
     - Desired direction of Main lobe
   - Hansen-Woodyard

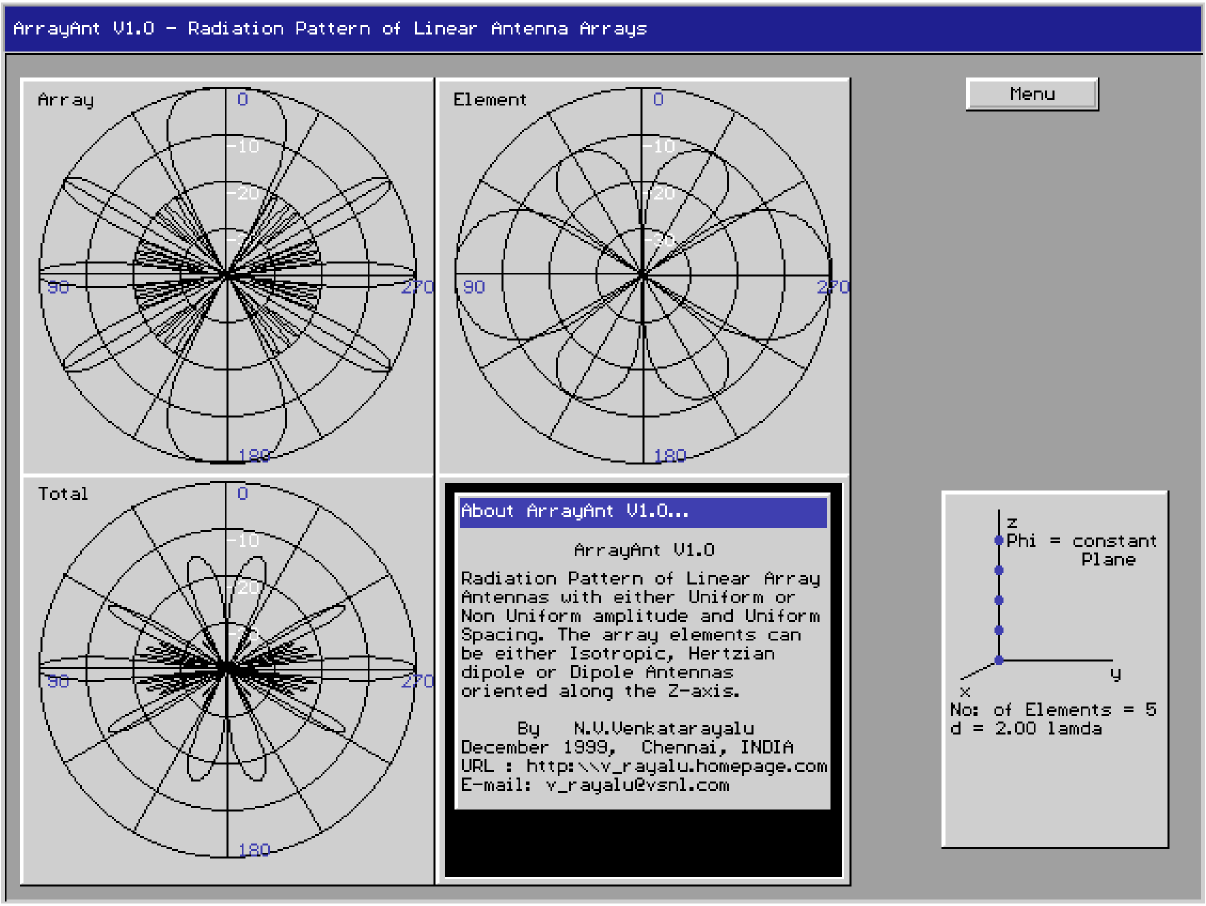
4. Number of Elements

5. Spacing Between the elements

Example:

Type of Amplitude Distribution:	Dolph- Chebyscheff
Major to Minor lobe ration:	20dB
Type of antenna element:	Dipole Antenna
Length f Dipole:	1.25 wavelengths
Type of Array:	BroadSide
Number of Elements	5
Spacing Between the elements	2 wavelengths

Computed Patterns:
Click the Patterns option in the menu or ‘p’ key to compute the radiation patterns.



Future developments:

For antenna modeling enthusiasts, this software can be further developed with incorporating the following features

1. Planar and 3-dimensinal array structures
2. Arbitrary placing of array elements in space, as defined by the user
3. Arbitrary current amplitudes in array elements
4. Arbitrary orientation of dipole antenna elements
5. Full 3-d radiation pattern plots