Design and Analysis Of Elliptical Array Antennas

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Abstract

An Elliptical Array Antenna is composed of a number of equally spaced array elements on the geometry of the ellipse. The aim of the project is to study the feasibility of using Elliptical Array Antenna for use at base stations. Elliptical Antenna Array arrangement has considerable effect on spatial correlation properties of multiple-input multiple-output (MIMO) wireless communication channels. In the method of beam steering and scanning Elliptical Arrays are presented. Theory, analysis, and computer simulation of the Elliptical Array Antenna are presented. The antenna array is designed using dipoles as array elements. The antenna is designed around 2GHz frequencies with a bandwidth of 200MHz.

The antenna is simulated using CST Microwave Studio and various radiation patterns are obtained by exciting different sets of array elements with different phase shifts between them. Elliptical Antenna Arrays are characterized by high directivities, narrow beams, and low side lobe levels. The output radiation patterns obtained for the antennas designed show that Elliptical Array Antennas can be used to generate high gain and minimum side lobe levels. Also, the variations in the radiation patterns are studied for this array antenna using different number of elements and different excitations with different phase shifts between the elements. The results are tabulated for each design.

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I. Introduction

In the 1890s, there were only a few antennas in the world. These rudimentary devices were primarily a part of experiments that demonstrated the transmission of electromagnetic waves. By World War II, antennas had become so ubiquitous that their use had transformed the lives of the average person via radio and television reception. The number of antennas in the United States was on the order of one per household, representing growth rivaling the auto industry during the same period.

By the early 21st century, thanks in large part to mobile phones, the average person now carries one or more antennas on them wherever they go (cell phones can have multiple antennas, if GPS is used, for instance). This significant rate of growth is not likely to slow, as wireless communication systems become a larger part of everyday life. In addition, the strong growth in RFID devices suggests that the number of antennas in use may increase to one antenna per object in the world [1].

Antenna is an essential device for transmission and reception over the specified frequency bandwidth. The performance of single antenna elements is poor compared to that of antenna arrays. In an antenna array, the number of elements, the spacing between them, their excitation coefficients, and their relative phases are parameters that can be adjusted not only to increase the antenna gain but also to narrow the beam (i.e. decrease the beam width), steer the beam in a given direction, and/or control the side lobes level (by adjusting the excitation coefficients of the antenna array) [2].

Widely used antenna arrays are the uniform linear arrays where the radiating elements are placed on a line with equal spacing and excitation in addition to uniform circular arrays where the radiating elements are uniformly distributed on a circle with equal excitations. Hybrid linear and circular antenna arrays are a class of antenna arrays combining the advantages of linear and circular arrays. Cylindrical arrays, a subclass of these hybrid arrays, emerged as the ones having the most interesting properties.

In this paper, various radiation patterns of an Elliptical Array were designed with different combinations of number of elements and inter element spacing and also all are examined based on different antenna parameters (Directivity, Gain, SLL, etc).

Multiple beams are obtained using the antenna array and it can be used to reject the interference in unwanted directions and direct the radiation towards the desired user.

II. Elliptical Array

An Elliptical Array is formed by placing the elements (dipoles) on the geometry of the ellipse. The spacing between the elements can be calculated based on the length of the major axis 'a' and length of the minor axis 'b' and also with the eccentricity 'e'.

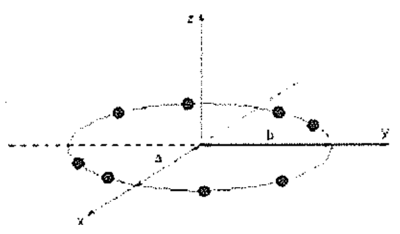

Fig 1. Elliptical Array structure

Array elements lie on the ellipse with eccentricity 'e'. When eccentricity e = 1, leads to circular array.

III. Description

In this chapter, the design details of Elliptical Array Antenna are presented which was simulated using CST Microwave Studio. The Elliptical Array designed is composed of the elements placed on the geometry of the ellipse. The elements used for the design of Elliptical Array Antenna are half-wave dipoles. The Elliptical Array antenna is designed for the frequency of 1.9 to 2.1 GHz range. The far fields were obtained for the central frequency of 2 GHz i.e. for a wavelength of 0.15m.

The design flow has following steps.

Units – The units for the dimensions of the design are initially chosen to be in centimeters (cm). The units for frequency are set to be in the Gigahertz (GHz) range and time in seconds.

- A normal thermal type of background material with unity epsilon and mue values is chosen.
- The type of material for the antenna elements i.e. for the dipoles is taken as perfect electrical conductor (PEC).
- The Elliptical antenna parameters major axis and minor axis are calculated based on the inter element spacing and length of the dipole. In the project, a spacing of λ/2 and λ/4 were tried for each case.
- The coordinates for placing the dipoles on the ellipse geometry are found based on (a cosθ, b sinθ) where a is the semi major axis and b is the semi minor axis.
- The type of dipoles used in the entire project is half-wave dipoles. Each dipole is created by selecting cylinders of radius 0.1cm and each pole

is approximately quarter wavelength. Each of these is placed at different positions on the circumference based on the coordinates calculated

- The frequency of operation is chosen to be in the range of 1.9 to 2.1 GHz.
- An open boundary on all sides is selected under the boundary conditions.
- To feed the dipoles with power, discrete S-parameter ports are selected with a power of 1W and resistance 50Ω.
- A Gaussian signal pulse of 2GHz is given as the excitation signal at the ports.
- The far fields are set to be calculated at the frequency of 2GHz
- The transient solver is chosen to generate electromagnetic field patterns.
- The number of ports to be excited and the amplitude and phase to excite each element is chosen.

IV. Simulation software

CST MICROWAVE STUDIO

CST Microwave Studio is a specialized tool for the fast and accurate 3D EM simulation of high frequency problems. Along with a broad application range, CST Microwave Studio® offers considerable product-to-market advantages: shorter development cycles; virtual prototyping before physical trials; optimization instead of experimentation. CST Microwave Studio is based on finite integration technique (FIT).

Main Features of CST Microwave Studio

➢ Transient Solver

➢ Transient solver for efficient calculation for loss-free and lossy structures. The solver does a broadband calculation of S-parameters from one single calculation run by applying DFT's to time signals.

➢ Frequency Domain Solver

➢ Frequency domain solver with adaptive sampling. The general purpose solver supports both, hexahedral and tetrahedral meshes.

➢ Besides the general purpose solver, the frequency domain solver also contains two solvers being specialized on strongly resonant structures (hexahedral meshes only). The first of these solvers does only calculate S-parameters whereas the second one also calculates fields which requires some additional calculation time.

The structure can be viewed either as a 3D model or as a schematic. The latter allows for easy coupling of the EM simulation with circuit simulation.

Far field (2D, 3D, gain, angular beam width and more) and radar cross section (RCS) calculation.

Network Parameter Extraction.

Fast and memory efficient FI-method.

V. Model Creation

CST Microwave Studio offers different options for shape creation to obtain desired models. The shapes are associated to "components." Each shape must have a unique name within a certain component. Components are useful to quickly manipulate a larger part of the model. Transformations can be applied to any shape to translate, rotate, scale or mirror a shape. Boolean operations are a very common way to produce complex shapes. With these operations, it is possible to Add, Subtract, Intersect, Insert and Imprint shapes into each other.

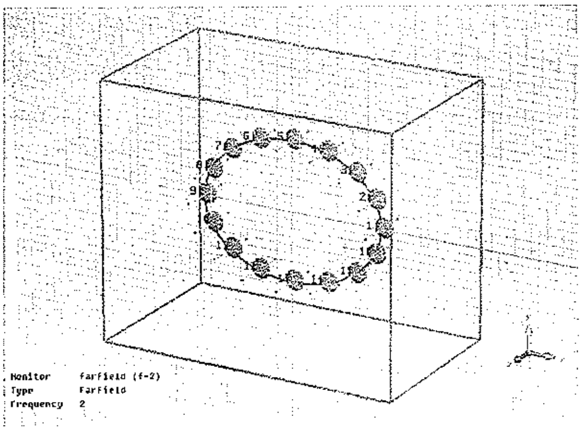

Figure 2: CST Microwave Studio view showing meshing and far field parameters of the antenna

VI. Designs

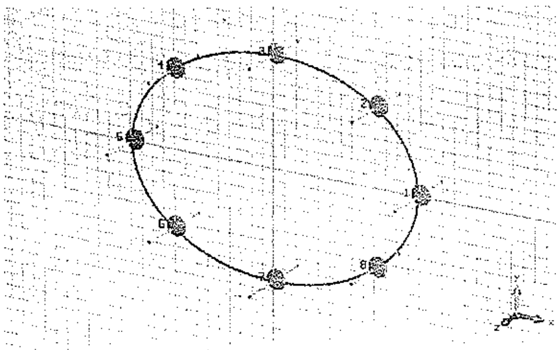

Figure 3. 8 element Elliptical Array with inter-element spacing λ/2

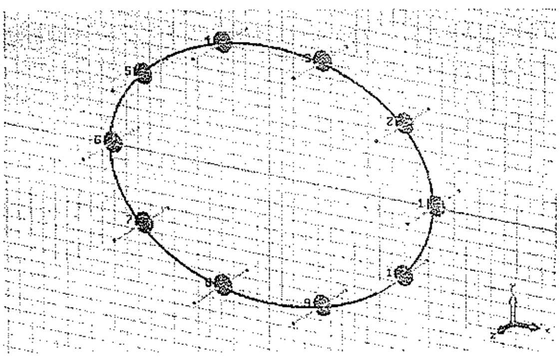

Figure 4 : 10 element Elliptical array with inter-element spacing λ/2

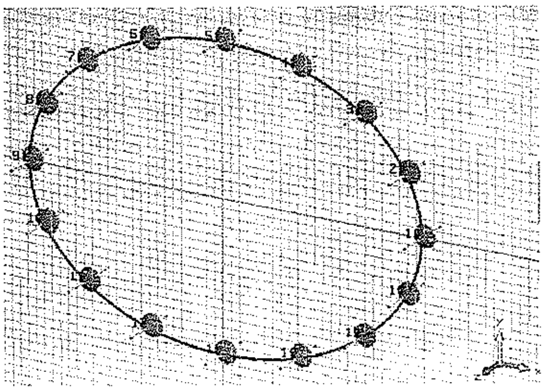

Figure 5: 16 element Elliptical Array with inter-element spacing λ/2

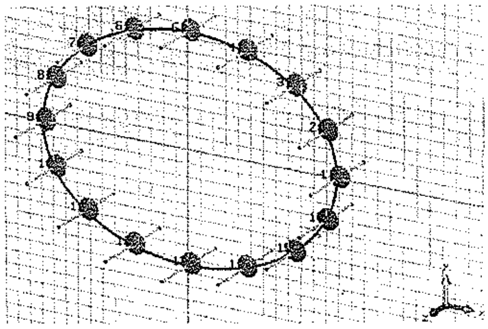

Figure 6: 16 element Elliptical Array with inter-element spacing λ/4

VII. Simulation Results

16 element Elliptical Array with inter-element spacing λ/2

Excitations	Phase shifts between elements in degrees	Directivity (dBi)	Gain (dBi)
All elements excited	0	4.84	4.835
	45	4.738	4.735
	90	4.776	4.771
	180	4.384	4.378
Eight elements excited	0	7.15	7.142
	45	7.153	7.149
	90	7.129	7.123
	180	6.382	6.381
Four elements excited	0	7.106	7.091
	45	6.745	6.743
	90	5.641	5.635
	180	8.089	8.088
Two element excited	0	7.106	7.091
	45	7.724	7.716
	90	7.014	7.007
	180	6.229	6.224
One element	-	7.294	7.292

VII. Conclusion

In this paper, different Elliptical Array antennas were designed and radiation patterns were observed. It was observed that as the number of elements in the array increases, the directivity increases. Also, by exciting different combinations of elements of the array different radiation patterns were obtained. The radiation pattern changes with the phase shift between the elements and also with the excitation elements.

Elliptical Array Antennas have special advantages over other array types. These are useful in beam steering and scanning purpose. By placing more number of elements on the ellipse, sharp main beams were obtained with nulls in the minor lobe direction. This can improve systems capability significantly of transmitting or receiving less interfering signals.

Future work of this paper will be the design of antennas which will improve signal capacity with reduced interference.

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Author's Biography

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